Watershed Hydrology and Water Quality Modeling Report

for

Floyds Fork, Kentucky

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PREPARED FOR:

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Environmental Protection Agency
Region 4
61 Forsyth Street, SW
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Revision History of the Floyds Fork Watershed Modeling Report

The following table presents the revision history of the Floyds Fork Watershed Modeling Report.

Table i-1 Revision History of Floyds Fork Watershed Modeling Report

Revision Number	Release Date	Comments
0	December 30, 2011	Initial Release of Report. Hydrology, Temperature/DO, Water Quality and Sediment Calibration/Validation.
1	January 31, 2012	Addressed comments from EPA Region 4.
2	May 4, 2012	Made minor text changes to document. Added Glossary of Terms. Added additional SSO's (section 3.9). Updated non-point source loading tables (section 3.13). Updated water quality scoring system (section 5.11). Added Section 5.12 – Loading Summary.
3	July 13, 2012	Updated point source representation. Updated land use water quality parameters. Updated water quality calibration.
4	August 30, 2012	Added clarifying information in the Meteorological Data (section 3.5). Added clarifying information in the Septics section (section 3.11). Added Springs in the model (section 3.13). Updated and added clarifying information on land use loading rates (section 3.14). Updated hydrology and land use water quality parameters. Updated hydrology and water quality calibration.
5	February 8, 2013	Incorporated miscellaneous comments from EPA, KDOW and Stakeholders into the report. Updated the point source assumption for individual family residences (section 3.8.2). Updated the failing rate for septic systems in Oldham County. Incorporated Jefferson County MSD's coverage for septic systems (section 3.11). Updated the sinkhole coverage (section 3.12). Updated Fertilizer and Manure based loading rates. Updated non-point source discharges (section 3.14). LSPC Model: FloydsFork_LSPC_Model_REV5
6	May 14, 2013	Addressed comments from EPA Region 4. Addressed comments from KDOW. Addressed comments from Stakeholders. Added clarifying information in the Point Sources section (section 3.8). Updated and added clarifying information on non-point sources discharges (section 3.14). Updated Fertilizer and Manure based loading rates (section 3.14.1 and 3.14.2). Updated Grassland loading rates (section 3.14.3). Updated the Urban loading rates (section 3.14.4). LSPC Model: FloydsFork_LSPC_Model_REV7

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GLOSSARY OF TERMS

ASAE: American Society of Agricultural Engineers. It is a professional and technical organization dedicated to the advancement of engineering applicable to agriculture, food and biological systems. Information provided on fresh manure production and characteristics per 1000lbs live animal mass per day was used in this model.

ASCII: American Standard Code for Information Interchange. The meteorological data was received in this format.

BASINS: Better Assessment Science Integrating Point & Non-Point Sources. It is a multi-purpose environmental analysis system that integrates a geographical information system, a national watershed data, and state-of-the-art environmental assessment and modeling tools into one convenient package.

BOD_5: 5-day Biochemical Oxygen Demand. It is the amount of oxygen utilized by the microorganisms in breaking down the waste.

CSOs: Combined Sewer Overflows. It contains stormwater in addition to untreated human and industrial waste. There were no reported CSOs to be used in the Floyds Fork watershed model.

DMR: Discharge Monitoring Report. It is a United States regulatory for a periodic water pollution report produced by industries, municipalities and other facilities discharging to surface waters

DO: Dissolved Oxygen. It is the measured oxygen in its dissolved form.

EPA: Environmental Protection Agency. This organization is a federal agency responsible for protecting human health and the environment, by enforcing regulations based on laws passed by Congress.

FTABLE: This table contains information on the reaches in a model. It consists of information on depth, surface area and volume.

HSG: Hydrologic Soil Group. Soils are assigned to these groups based on measured rainfall, runoff and infiltration data.

HSPF: Hydrologic Simulation Program FORTRAN. It is used for simulation of watershed hydrology and water quality for both conventional and toxic organic pollutants.

HTRCH: It is a subroutine in HSPF/LSPC that simulates heat exchange and water temperature.

HUC: Hydrologic Unit Code. It is a watershed identifier. This is a standardized watershed classification system developed by United States Geological Survey.

IQUAL: It is a subroutine in HSPF/LSPC that simulates the wash-off of quality constituents associated with particulates using simple relationships.

IWATER: It is a subroutine in HSPF/LSPC that simulates the water budget for impervious land segment.

IWTGAS: It is a subroutine in HSPF/LSPC that estimates water temperatures and dissolved gas concentrations on a segment of impervious land.

KDOW: Kentucky Division of Water. This organization is responsible for protecting, managing and enhancing the quality of the Commonwealth's water resources through voluntary, regulatory and educational programs.

KGS: Kentucky Geological Survey. This organization is responsible for providing the citizens, researchers, industries and government, with scientifically based information on Kentucky's geology, mineral and water resources.

KPDES: Kentucky Pollutant Discharge Elimination System. As authorized by Clean Water Act, KPDES permit program is responsible for controlling water pollution by regulating point sources that discharge pollutants into Kentucky waters. 73 KPDES facilities were identified and used in the Floyds Fork model.

LSPC: Loading Simulation Program in C++. It is a watershed modeling system that includes streamlined HSPF algorithms for simulating hydrology, sediment and general water quality on land as well as a simplified stream transport model. This modeling system was used for the Floyds Fork watershed model.

MDAS: Mining Data Analysis System.

MGD: Million Gallons per Day. This is the unit used by most of the agencies to report flows/overflows.

MON-ACCUM: This subroutine simulates the monthly accumulation of solids independently of runoff.

MRLC: Multi-Resolution Land Characteristics Consortium. It is a group of federal agencies who coordinate and generate consistent and relevant land cover information at a national level. The land use coverage for this model was used from this agency.

MSD: Municipal Sewer District. It is a non-profit regional utility service. It is responsible for the operation and maintenance of Louisville's combined sanitary and storm sewer system and sanitary-only sewer system. Part of the water quality data, information on CSOs and SSOs used in the Floyds Fork model was obtained from MSD.

NCDC: National Climate Data Center. It is the world's largest active archive of weather data. Weather data for Floyds Fork model was obtained from this agency.

NED: National Elevation Dataset. It is a seamless dataset that contains the best raster elevation data of the conterminous United States. NED of 1/3-arc second resolution was used in the Floyds Fork model.

NGMC (formerly known as NCGC): National Geospatial Management Center. It is a major distributor of geospatial data. It provides technical leadership and expertise in geosciences like geographic information system (GIS), aerial photography, remote sensing and elevation.

NHD: National Hydrography Dataset. It is the surface water component of the National map. The NHD is a digital vector dataset used by GIS. This data is designed to be used in surface water systems. The sub-watersheds for the Floyds Fork model were developed using the NHD catchment data layer (1:100,000) that was obtained from the United States Geological Survey (USGS).

NH_3: Ammonia.

NLCD: National Land Cover Database. It is a land cover mapping program. MRLC has been working towards making NLCD a land-cover monitoring program. For the Floyds Fork model, NLCD coverage for the year 2006 was used.

NOX: Nitrite-Nitrate.

NPDES: National Pollutant Discharge Elimination System. It is a permit program that controls water pollution by regulating point sources that discharge pollutants into waters of United States.

NRCS: National Resources Conservation Service. This agency is the conservation leader for all natural resources, and ensures that the private lands are conserved and restored.

ORGN: Organic Nitrogen.

ORGP: Organic Phosphorus.

OXRX: It is a subroutine in HSPF/LSPC that simulates primary DO and BOD balances.

EPA PCS: Environmental Protection Agency's Permit Compliance System. It is a national computerized management information system that automates the NPDES/KPDES data. It was used to retrieve information on the NPDES/KPDES permits for the Floyds Fork model.

PO_4: Orthophosphate.

P_2O_5: Phosphorus Pentaoxide.

PQUAL: This module in HSPF/LSPC allows data to be entered for the water quality constituents from a pervious land segment.

PSTEMP: This subroutine simulates soil temperatures for the surface, upper and lower layers of a land segment.

PWTGAS: It is a subroutine in HSPF/LSPC that estimates water temperatures and dissolved gas concentrations on a segment of pervious land.

PWATER: This subroutine is used to calculate the components of the water budget, primarily to predict the total runoff from a pervious area.

RMU: Reduced Modeling Unit. This is used to condense similar land uses into one land use type in the model. There were two RMUs used in the Floyds Fork watershed model for Forest and Wetlands land uses.

SA: Surface Airways. NCDC Surface Airways contains hourly weather observations from the meteorological stations used in this model.

SEDMNT: This subroutine simulates the production and removal of sediment from a pervious land segment.

SEDTRN: It is a subroutine in HSPF/LSPC that simulates the behavior of inorganic sediments.

SOD: Summary of the Day. NCDC Summary of the Day contains daily weather observations from the meteorological stations used in this model.

SOLIDS: This subroutine simulates the accumulation and removal of solids by runoff and other means from impervious land segment.

SSOs: Sanitary Sewer Overflows. They are occasional, yet unintentional discharges of raw sewage from municipal sanitary sewers. SSOs from 8 NPDES facilities were identified for this model.

SSURGO: Soil Survey Geographic Database. It is the digital soils data produced and distributed by NRCS-NCGC. This database was used to retrieve the soils information for Floyds Fork watershed model.

TMDL: Total Maximum Daily Load. It is the maximum amount of pollutants that a waterbody can receive and still safely meet water quality standards.

TP: Total Phosphorus.

TN: Total Nitrogen.

TSS: Total Suspended Solids.

USGS: United States Geological Survey. It is a science organization that provides reliable scientific information to describe and understand the Earth and enhances and protects the quality of life.

WASP: Water Quality Analysis and Simulation Program. It is a dynamic compartment-modeling program for aquatic systems, simulating one-dimensional, two-dimensional, and three-dimensional systems, and a variety of pollutants.

WQTC: Water Quality Treatment Center.

WSQOP: It is the rate of surface runoff that results in 90% washoff in one hour.

WTEMP: Water Temperature.

1.0 INTRODUCTION

Floyds Fork is comprised of two 10-digit HUC watersheds, Upper Floyds Fork (HUC 0514010208) and the Lower Floyds Fork (HUC 0514010210) watershed in northwestern Kentucky. Geographically, Floyds Fork originates in the southwestern portion of Henry County and flows southwest for about 62 miles to its confluence with the Salt River in Bullitt County which then flows into the Ohio River. Floyds Fork is a major tributary of the Salt River. Its drainage area is 285 sq. miles and is within the Salt River basin which represents a significant part of central Kentucky. A total of 6 counties (Bullitt, Henry, Jefferson, Oldham, Shelby and Spencer) are partially located in the Floyds Fork watershed, making the watershed very important to a wide-range of communities. Figure 1-1 shows Floyds Fork, the Floyds Fork watershed, surrounding Counties and other features of the watershed. This report documents the development and calibration of a watershed model that will be used to approximate watershed flows, temperature, sediments, dissolved oxygen, and nutrient loadings entering Floyds Fork.

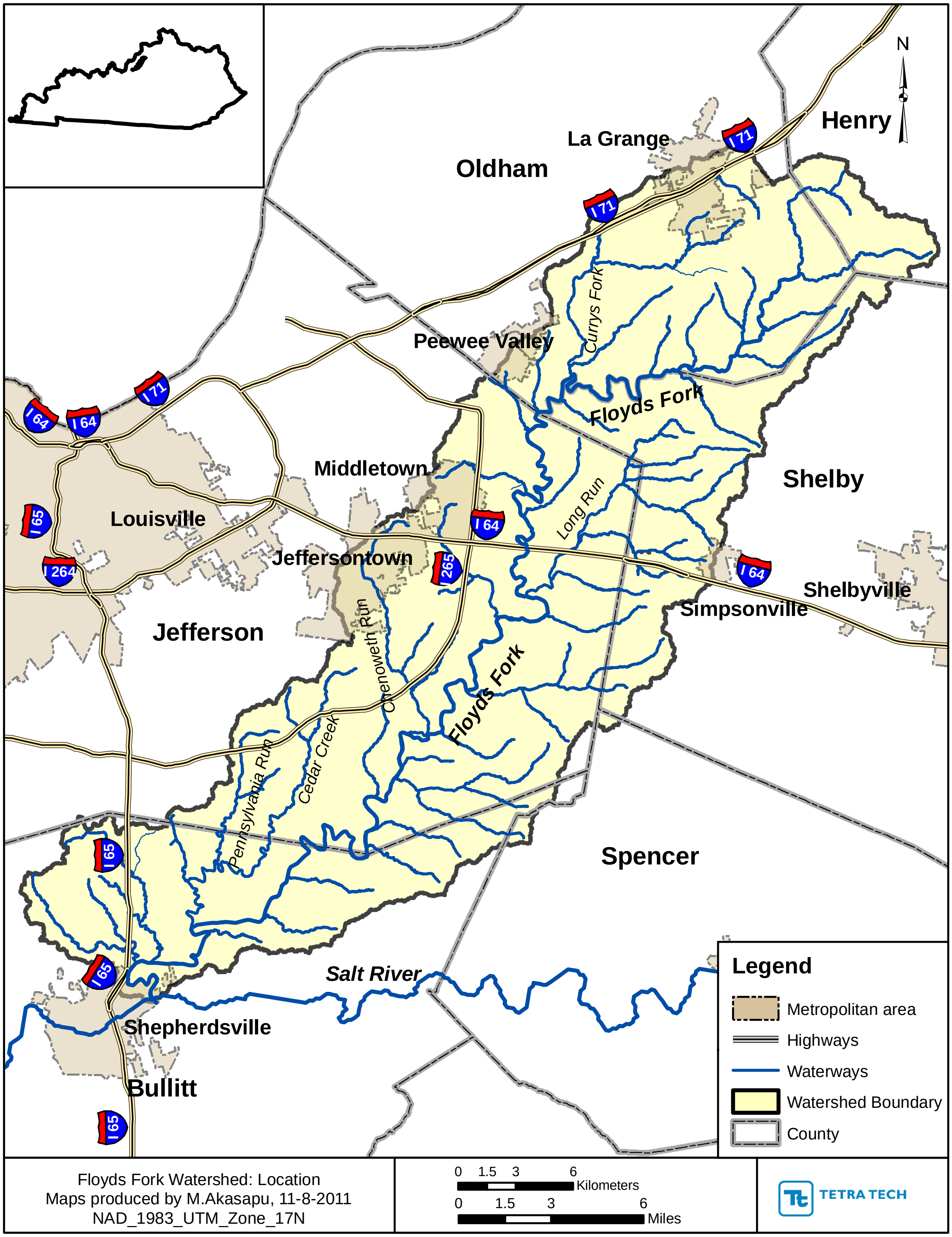


Figure 1-1 Location of Floyds Fork Watershed

2.0 MODEL SELECTION

2.1 LSPC Watershed Model

The Loading Simulation Program C++ (LSPC) was used to develop a watershed model to represent the hydrological and water quality conditions in the Floyds Fork watershed. LSPC is a comprehensive data management and modeling system that is capable of representing loading, both flow and water quality, from point and non-point sources and simulating in-stream processes. It is a dynamic watershed model driven by time-variable weather input data and can simulate flow, sediment, metals, nutrients, pesticides, and other conventional pollutants, as well as temperature and pH for pervious and impervious lands and waterbodies. LSPC was configured to simulate the watershed as a series of hydraulically connected sub-watersheds in which the model will estimate the surface water runoff and the advective transport of constituents. LSPC is based on the Mining Data Analysis System (MDAS), with modifications for non-mining applications such as nutrient and fecal coliform modeling. MDAS was developed by EPA Region 3 through mining TMDL applications.

2.2 Integration of LSPC with WASP

To address the nutrient loadings and the water quality standards for chlorophyll-a and dissolved oxygen, an in-stream water quality model will also be developed. The Water Quality Analysis Simulation Program (WASP 7.x) will be utilized as the water quality model. WASP is a dynamic compartment-modeling program for aquatic systems, simulating one-dimensional, two-dimensional, and three-dimensional systems, and a variety of pollutants. It is capable of simulating four classes of algae (three free floating and one benthic algae class), sediment-water oxygen, pH/alkalinity and nutrient exchanges. LSPC will be linked to the WASP model by providing flows and concentrations at tributaries and local drainage areas. WASP will then be used to simulate the in-stream water quality of Floyds Fork.

3.0 WATERSHED MODEL DEVELOPMENT

3.1 Overview

The watershed model represents the variability of non-point source contributions through dynamic representation of hydrology and land practices. The watershed model includes contributions from all point and non-point sources. Key components of the watershed modeling include:

- Watershed delineation (Section 3.2)
- Simulation period (Section 3.3)
- Soils (Section 3.4)
- Meteorological data (Section 3.5)
- Reach Characteristics (Section 3.6)
- Land use representation (Section 3.7)
- Point Source Discharges (Section 3.8)
- Sanitary Sewer Overflows (Section 3.9)
- Industrial Water Withdrawals (Section 3.10)
- Septic Tanks (Section 3.11)
- Sinkholes (Section 3.12)
- Springs (Section 3.13)
- Non-Point Source Discharges (Section 3.14)
- Hydrologic representation (Section 4.1)
- Observed Flow Data (Section 4.2)
- Hydrology Calibration (Section 4.3)
- Hydrology Validation (Section 4.4)
- Hydrology Observations and Conclusions (Section 4.5)
- Water Quality Model Overview (Section 5.1)
- Modeled Parameters (Section 5.2)
- Reach Group Representation (Section 5.3)
- Temperature Representation (Section 5.4)
- Dissolved Oxygen Representation (Section 5.5)
- Sediment Representation (Section 5.6)
- Nutrient Representation (Section 5.7)
- Water Quality Development and Calibration (Section 5.8)
- Special Considerations for Water Quality (Section 5.9)
- Observed Water Quality Data Calibration and Validation (Section 5.10)
- Water Quality Observations and Conclusions (Section 5.11)
- Loading Summary (Section 5.12)

3.2 Watershed Delineation

In order to evaluate the sources contributing to an impaired waterbody and to represent the spatial variability of these sources within the watershed model, the contributing drainage area was represented by a series of sub-watersheds. The sub-watersheds were developed using the National Hydrography Dataset (NHD) catchment data layer (1:100,000) that was obtained from the United States Geological Survey (USGS). The Floyds Fork watershed consisted of 166 sub-watersheds, based on the NHD coverage (Figure 3-1). These sub-watershed representations were used as a guideline for further delineations.

The entire Floyds Fork watershed was further delineated into 202 sub-watersheds to provide appropriate hydrological connectivity. The sub-watersheds were delineated using the National Elevation Dataset (NED) in 1/3-arc-second resolution, USGS flow gage stations, USGS water quality monitoring stations, and other points of interest. The NED coverage is shown in Figure 3-2 whereas, the USGS flow gage and water quality monitoring stations along with other points of interest for the Floyds Fork watershed is shown in Figure 3-3.

Occasionally, the delineations resulted in two sub-watersheds contributing to either a calibration or validation station location. Since the observed data at this station reflects hydrologic and water quality conditions of the combination of the two sub-watersheds, an additional sub-watershed was created to join the two sub-watersheds together. This was done to aid in comparing observed data and simulated results. In the Floyds Fork watershed, these additional sub-watersheds were created at 19 locations. These additional sub-watersheds do not affect the calibration or validation of the model.

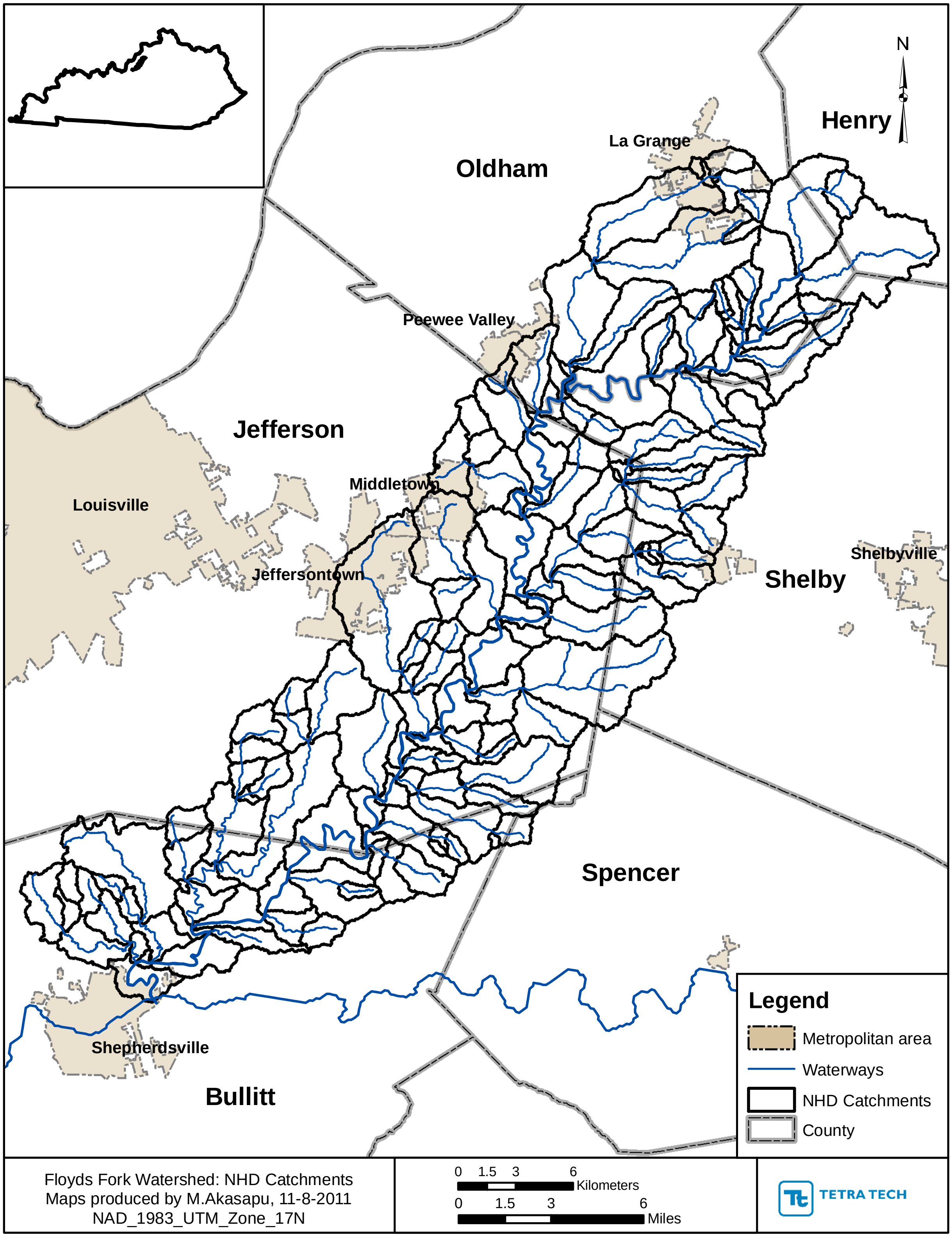


Figure 3-1 NHD Catchment Coverage for the Floyds Fork Watershed

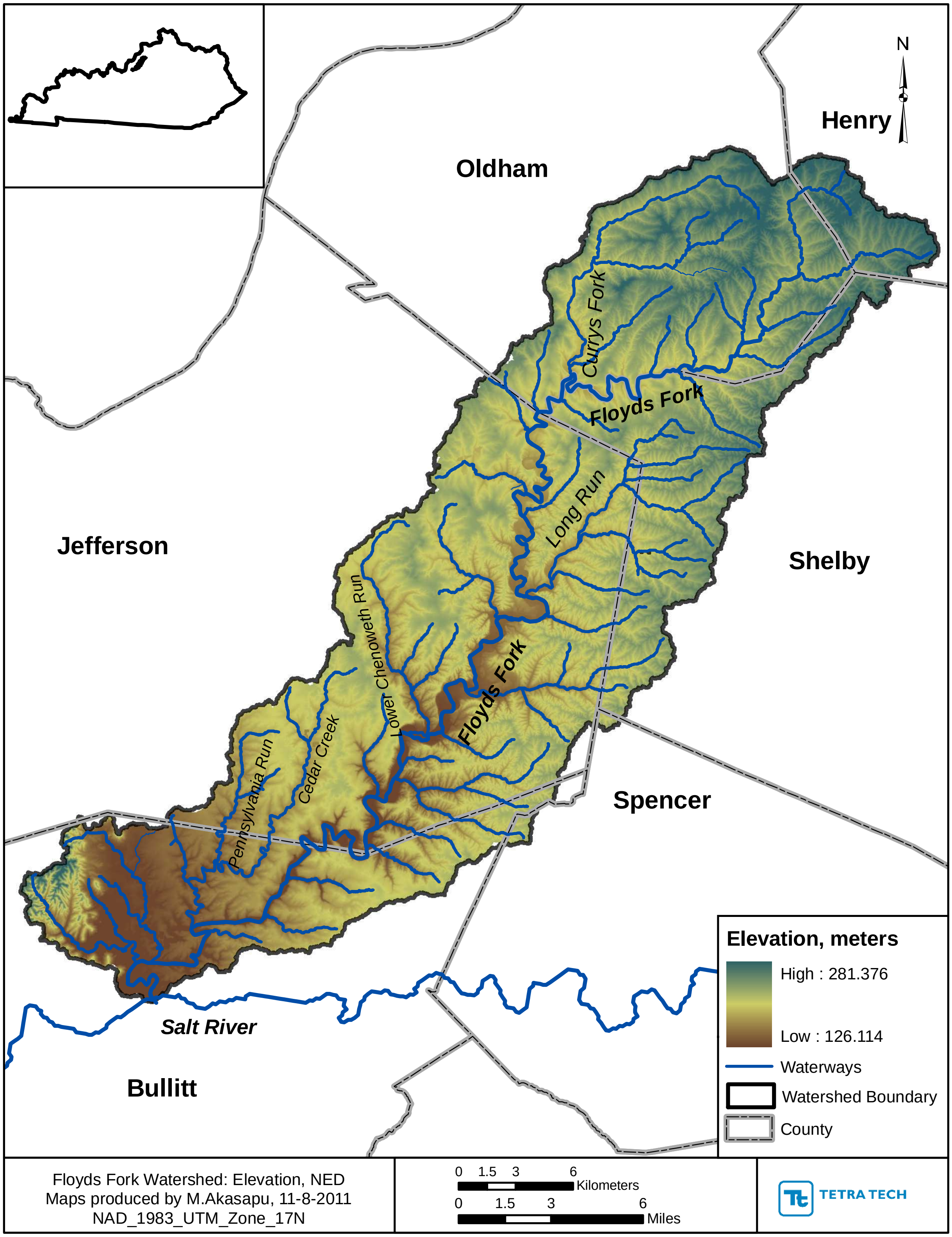


Figure 3-2 National Elevation Dataset (NED) Coverage of the Floyds Fork Watershed

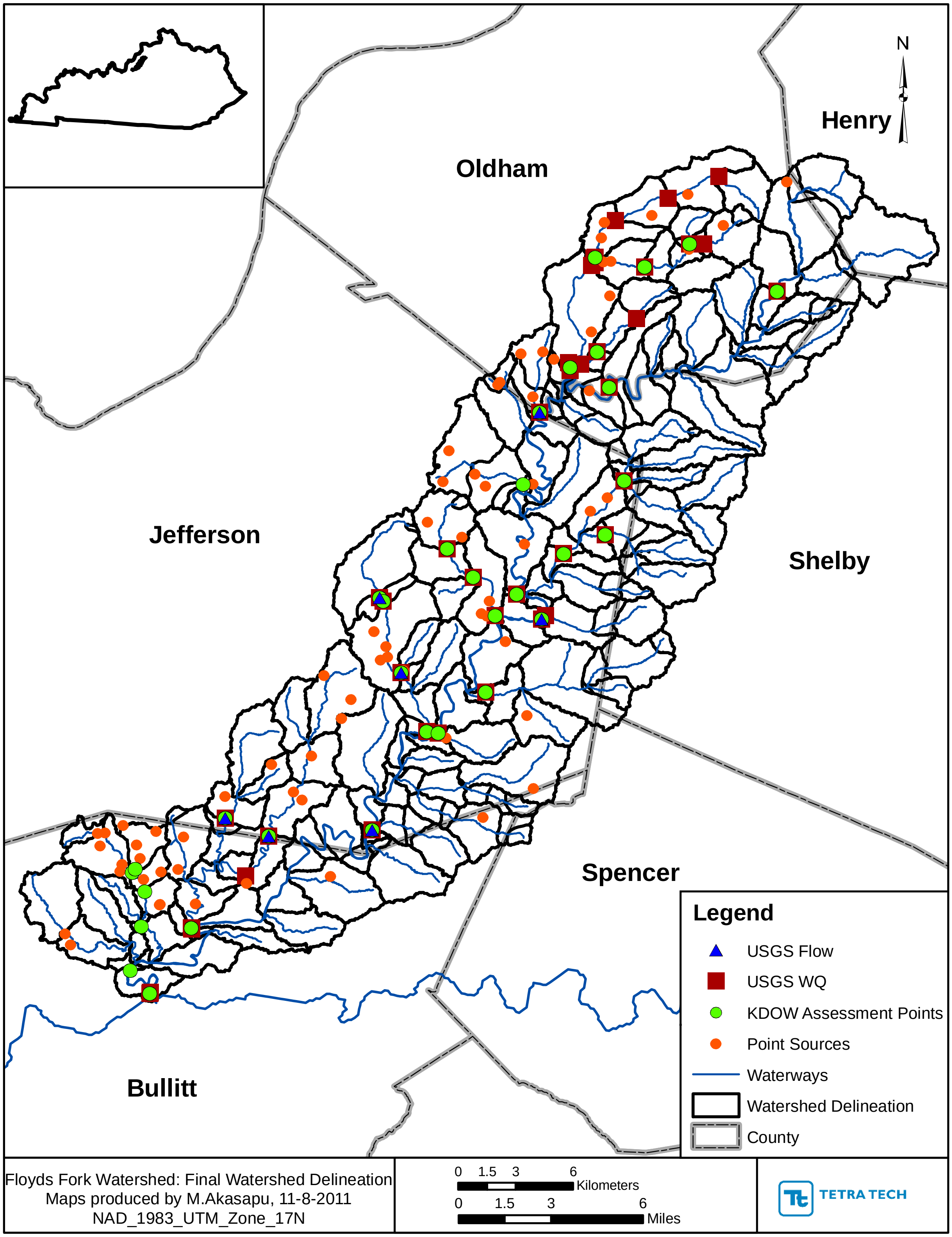


Figure 3-3 Sub-delineated Coverage for the Floyds Fork Watershed

3.3 Simulation Period

The USGS recommends looking at a minimum of a 10-year time period for hydrology calibrations. This is due to the fact that over a 10-year period, a variety of hydrological conditions will exist, and a model that is calibrated over this time period will have a greater chance of success in capturing the trends and processes as well as predicting future hydrological conditions. The LSPC model was simulated for the 10-year period from January 1, 2001 through December 31, 2010. This time period was selected due to the difficulty of acquiring data prior to 2001. In addition, this period captured wet, drought and normal years very well. To allow the model plenty of “spin-up” time, the model was run for a full year (January 2000 to December 2000) before the simulation period began.

3.4 Soils

Soils data for the Floyds Fork watershed was obtained from the Soil Survey Geographic Database (SSURGO). This database was produced and distributed by the Natural Resources Conservation Service (NRCS) - National Geospatial Management Center (NGMC), formerly National Cartography and Geospatial Center (NCGC). The SSURGO data was used to determine the total area that each hydrologic soil group covered within each sub-watershed. The sub-watersheds were represented by the Hydrologic Soil Group (HSG) that had the highest percentage of coverage within the boundaries of the sub-watershed. All of the Floyds Fork sub-watersheds were dominated by the Group C HSG as shown in Figure 3-4. The soil group is described below:

<u>Group C Soils</u> Have low infiltration rates when thoroughly wet, thus having a moderate to high runoff potential, and consist chiefly of soils with a layer that delays the downward movement of water and soils with moderately coarse textures.

In LSPC, each dominant HSG within the study watershed is assigned a default group number. A standard approach for assigning HSGs to default group numbers included: Group A equals 1, Group B equals 2, Group C equals 3 and Group D equals 4. Although the soils coverage under the heavily impervious land use was labeled as ‘Not assessed’ (see Figure 3-4), in the LSPC model, it was assigned the HSG that covered the next highest area within the sub-watershed.

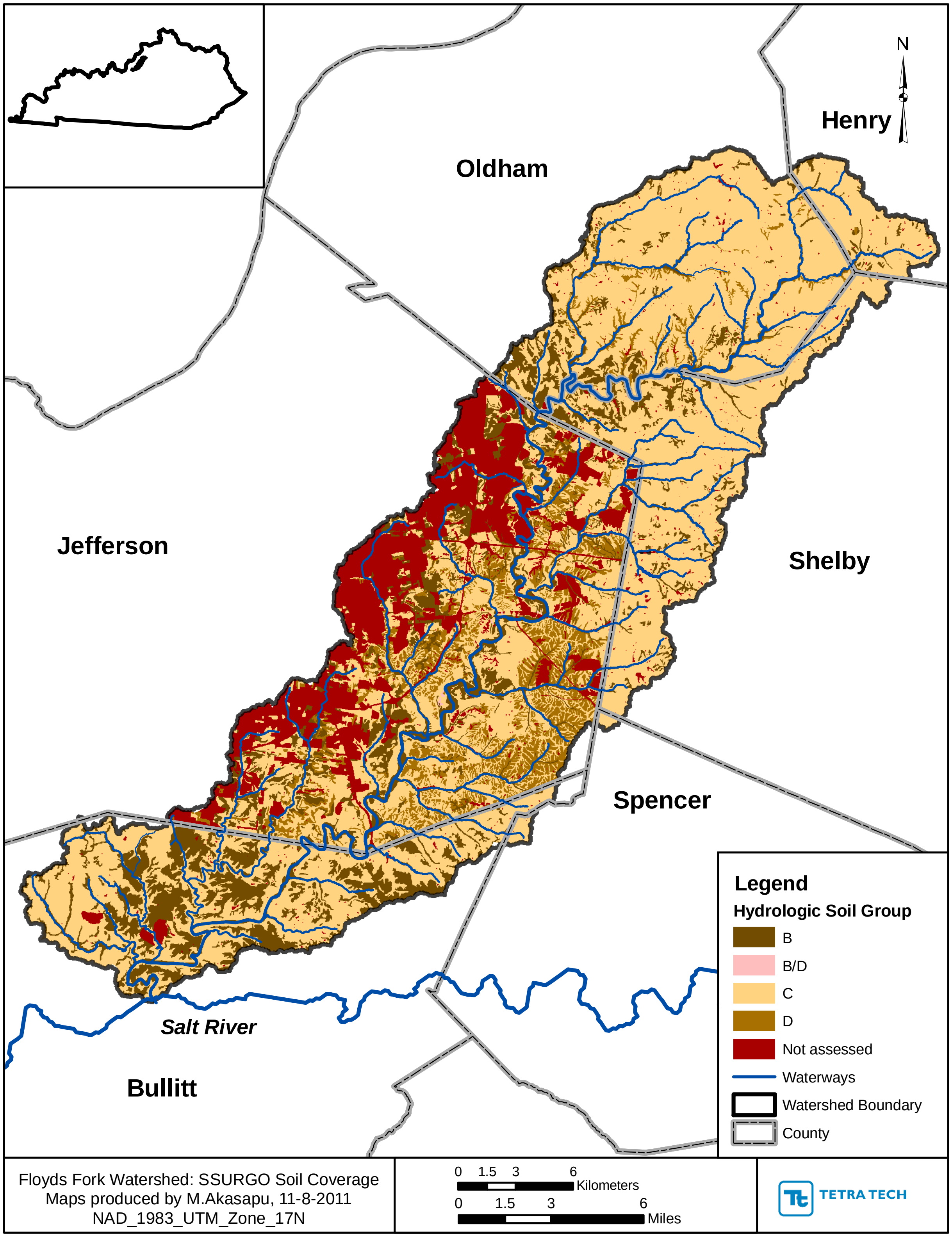


Figure 3-4 Soils Coverage for the Floyds Fork Watershed

3.5 Meteorological Data

Non-point source loadings and hydrological conditions are dependent on weather conditions. Hourly data from weather stations within the boundaries of, or in close proximity to the sub-watersheds were applied to the watershed model. An ASCII file (*.air) was generated for each meteorological and precipitation station used for the hydrologic evaluations in LSPC. Each meteorological and precipitation station file contains atmospheric data used for modeling of the hydrologic processes. These data include precipitation, air temperature, dew point temperature, wind speed, cloud cover, evaporation, and solar radiation. These data are used directly, or calculated from the observed data.

For the Floyds Fork watershed, 1 meteorological station, 1 mesonet and 37 precipitation stations were available, out of which 3 precipitation stations were used in the hydrologic simulations. Out of the 37 precipitation stations, 7 stations were from Jefferson County Municipal Sewer District (MSD) and the remaining were National Climate Data Center (NCDC) stations. The 39 total weather stations are listed in Table 3-1 and the 3 stations used in the hydrologic simulations have been highlighted. The percent of weather data patched for each of the weather stations is also tabulated in Table 3-1. These stations are shown spatially in Figure 3-5. The precipitation stations used in the model were NCDC Summary of the Day (SOD) and Surface Airways (SA) stations. SOD stations record daily precipitation, and daily minimum and maximum temperatures. Since SOD stations only provided daily precipitation and temperature, the NCDC SA station was used to disaggregate daily values to hourly as well as assign hourly values for dew point, wind speed, cloud cover, evaporation and solar radiation.

Weather stations were assigned to the sub-watersheds using a Thiessen polygon. If a particular watershed was intersected by the polygon boundary, it was assigned to the station that had the greatest area covered by that station's polygon.

Table 3-1 Available Weather Stations in the Floyds Fork Watershed

Weather Station	Staion ID	Station Name	Type	Agency	Elevation (ft)	State	County	Latitude	Longitude	% Complete	% Patched
1	13810_uo	Lou -Bowman Field Airport	Meteorological	NCDC	540	KY	Jefferson	38.228	-85.664	37	63
2	CRMT	Sheperdsville 6 Se	Mesonet	KY Mesonet	546	KY	Bullitt	37.920	-85.660	-	-
3	121814	Corydon	Precipitation	NCDC	590	IN	Harrison	38.218	-86.118	100	0
4	124977	Lexington 3 N	Precipitation	NCDC	630	IN	Scott	38.675	-85.603	78	22
5	127875	Scottsburg	Precipitation	NCDC	570	IN	Scott	38.689	-85.785	66	34
6	150397	Bardstown 5 E	Precipitation	NCDC	780	KY	Nelson	37.819	-85.385	100	0
7	150630	Bernheim Forest	Precipitation	NCDC	550	KY	Bullitt	37.916	-85.657	98	2
8	150875	Boston 6 Sw	Precipitation	NCDC	820	KY	Hardin	37.744	-85.748	100	0
9	150955	Brandenburg	Precipitation	NCDC	655	KY	Meade	37.956	-86.114	100	0
10	151251	Campbellsburg	Precipitation	NCDC	875	KY	Henry	38.516	-85.232	76	24
11	151900	Crestwood 4 Ne	Precipitation	NCDC	780	KY	Oldham	38.364	-85.419	100	0
12	152500	Elizabethtwn Ksp Pst 4	Precipitation	NCDC	780	KY	Hardin	37.712	-85.831	100	0
13	152512	Elizabethtown Wp C S	Precipitation	NCDC	687	KY	Hardin	37.679	-85.878	99	1
14	153030	Frankfort State Police	Precipitation	NCDC	755	KY	Franklin	38.179	-84.901	100	0
15	154954	Louisville Wsfo Ap	Precipitation	NCDC	481	KY	Jefferson	38.177	-85.730	100	0
16	154955	Louisville Upper Gage	Precipitation	NCDC	440	KY	Jefferson	38.283	-85.800	100	0
17	157334	Shepherdsville 5 Ne	Precipitation	NCDC	580	KY	Bullitt	38.054	-85.624	98	2
18	157604	Springfield	Precipitation	NCDC	760	KY	Washington	37.694	-85.234	100	0
19	157948	Taylorsville 2 Sw	Precipitation	NCDC	500	KY	Spencer	38.014	-85.371	100	0
20	154746	Lexington Bluegrass	Precipitation	NCDC	980	KY	Fayette	38.033	-84.600	100	0
21	IN1814	Corydon	Precipitation	NCDC	590	IN	Harrison	38.218	-86.118	31	69
22	IN6697	Palmyra	Precipitation	NCDC	770	IN	Harrison	38.408	-86.111	24	76
23	KY4954	Louisville Wsfo Ap	Precipitation	NCDC	481	KY	Jefferson	38.177	-85.730	64	36
24	KY4955	Louisville Upper Gage	Precipitation	NCDC	440	KY	Jefferson	38.283	-85.800	38	62
25	KY7074	Sadieville	Precipitation	NCDC	945	KY	Scott	38.408	-84.684	40	60
26	KY7096	St Mary	Precipitation	NCDC	743	KY	Marion	37.583	-85.350	0	100
27	KY7473	Smithfield 4 S	Precipitation	NCDC	850	KY	Shelby	38.333	-85.286	47	53
28	KY8719	Willisburg	Precipitation	NCDC	870	KY	Washington	37.801	-85.113	37	63
29	93820_uo	Klex - Blue Grass Airport	Precipitation	NCDC	980	KY	Fayette	38.041	-84.606	100	0
30	93821_uo	Ksdf - Louisville Intl-Standiford Field Ap	Precipitation	NCDC	488	KY	Jefferson	38.177	-85.730	100	0
31	63838_uo	7350 -University Of Kentucky	Precipitation	NCDC	891	KY	Woodford	38.094	-84.746	31	69
32	53841_uo	Fft - Capital City Airport	Precipitation	NCDC	804	KY	Franklin	38.185	-84.903	100	0
33	TR15	Jeffersontown Wqtc	Precipitation	MSD	594	KY	Jefferson	38.193	-85.555	-	-
34	TR09	Cedar Creek Wqtc	Precipitation	MSD	623	KY	Jefferson	38.119	-85.594	-	-
35	TR10	Camp Horine(Jefferson Forest)	Precipitation	MSD	873	KY	Jefferson	38.078	-85.753	-	-
36	TR11	Northern Ditch Ps	Precipitation	MSD	459	KY	Jefferson	38.158	-85.757	-	-
37	TR14	Lea Ann Way Ps	Precipitation	MSD	469	KY	Jefferson	38.148	-85.669	-	-
38	TR08	Fern Creek Fire Station #3	Precipitation	MSD	728	KY	Jefferson	38.127	-85.470	-	-
39	TR01	D. R . Guthrie Wqtc	Precipitation	MSD	433	KY	Jefferson	38.086	-85.893	-	-

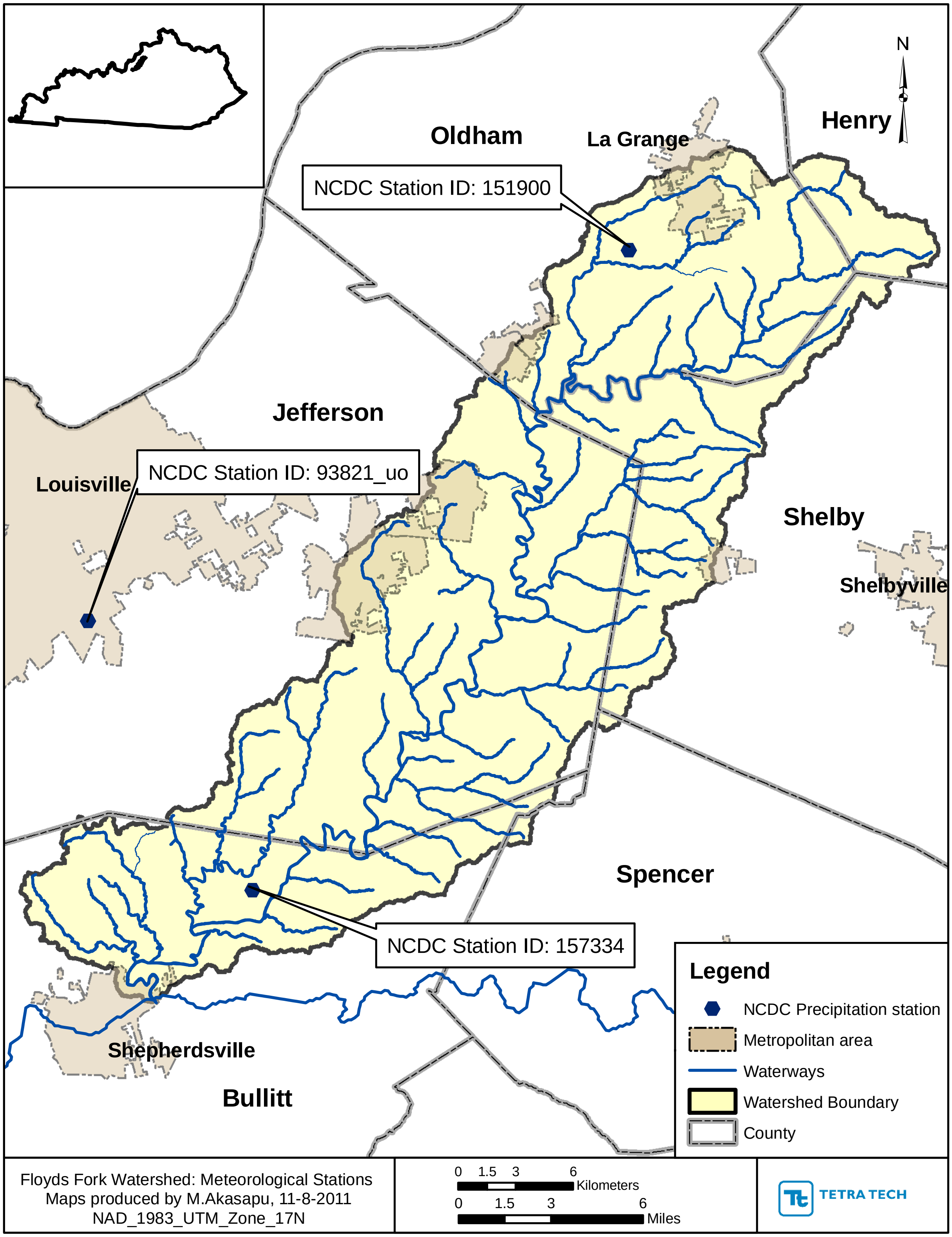


Figure 3-5 Location of Weather Stations used in the LSPC Watershed Model

3.6 Reach Characteristics

The LSPC model must have a representative reach defined for each sub-watershed. The characteristics for each reach include the length and slope of the reach, the channel geometry and the connectivity between the sub-watersheds. Length and slope data for each reach was obtained using the National Elevation Dataset (NED) and the National Hydrography Dataset (NHD). The channel geometry is described by a bank full width and depth (the main channel), a bottom width factor, a flood plain width factor and slope of the flood plain.

LSPC takes the attributes supplied for each reach and develops a function table, or FTABLE. The FTABLE describes the hydrology, of a river reach or reservoir segment, by defining the functional relationship between water depth, surface area, water volume, and outflow in the segment. The assumption of a fixed depth, area, volume, and outflow relationship rules out cases where the flow reverses direction or where one reach influences another upstream of it in a time-dependent way. The routing technique falls in the class known as "storage routing" or "kinematic wave" methods. In these methods, momentum is not considered (EPA, 2007).

3.7 Land Use Representation

The watershed model uses land use data as the basis for representing hydrology and non-point source loadings. Land use data was obtained from the Multi-Resolution Land Characteristics Consortium (MRLC) - National Land Cover Database (NLCD), and included the following 15-Class categories: Open Water, Developed Open Space, Developed Low Intensity, Developed Medium Intensity, Developed High Intensity, Barren, Deciduous Forest, Evergreen Forest, Mixed Forest, Shrub/Scrub, Grassland/Herbaceous, Pasture/Hay, Cultivated Crops, Woody Wetlands and Emergent Herbaceous Wetlands. The NLCD coverage represented conditions in the year 2006 and is shown in Figure 3-6. For the LSPC simulation, similar land use classes were grouped together into reduced modeling units (RMU) shown in Figure 3-7. For example, Deciduous Forest, Evergreen Forest and Mixed Forest were grouped together into an RMU called Forest.

The LSPC model requires division of land uses in each sub-watershed into separate pervious and impervious land units. For this, the NLCD impervious cover, Figure 3-8, was intersected with the NLCD land use cover. Any impervious areas associated with Developed Open Space and Developed Low Intensity, were grouped together and placed into a new RMU for Low Intensity Development Impervious. Impervious areas associated with Medium Intensity Development and High Intensity Development, were kept separate and placed into two new RMU's for Medium Intensity Development Impervious and High Intensity Development Impervious, respectively. Finally, any impervious area not already accounted for in the three developed impervious RMU's, were grouped together into a fourth new RMU, called "All Other Impervious".

Amendments were made to the NLCD land use in order to incorporate Failing Septic Tanks and Sinkholes into the model. Table 3-2 lists the land use categories used in the LSPC model with their respective areas. Sections 3.11 and 3.12 discuss where the data sets were obtained from, how they were processed, and how they were incorporated as unique land uses into the model.

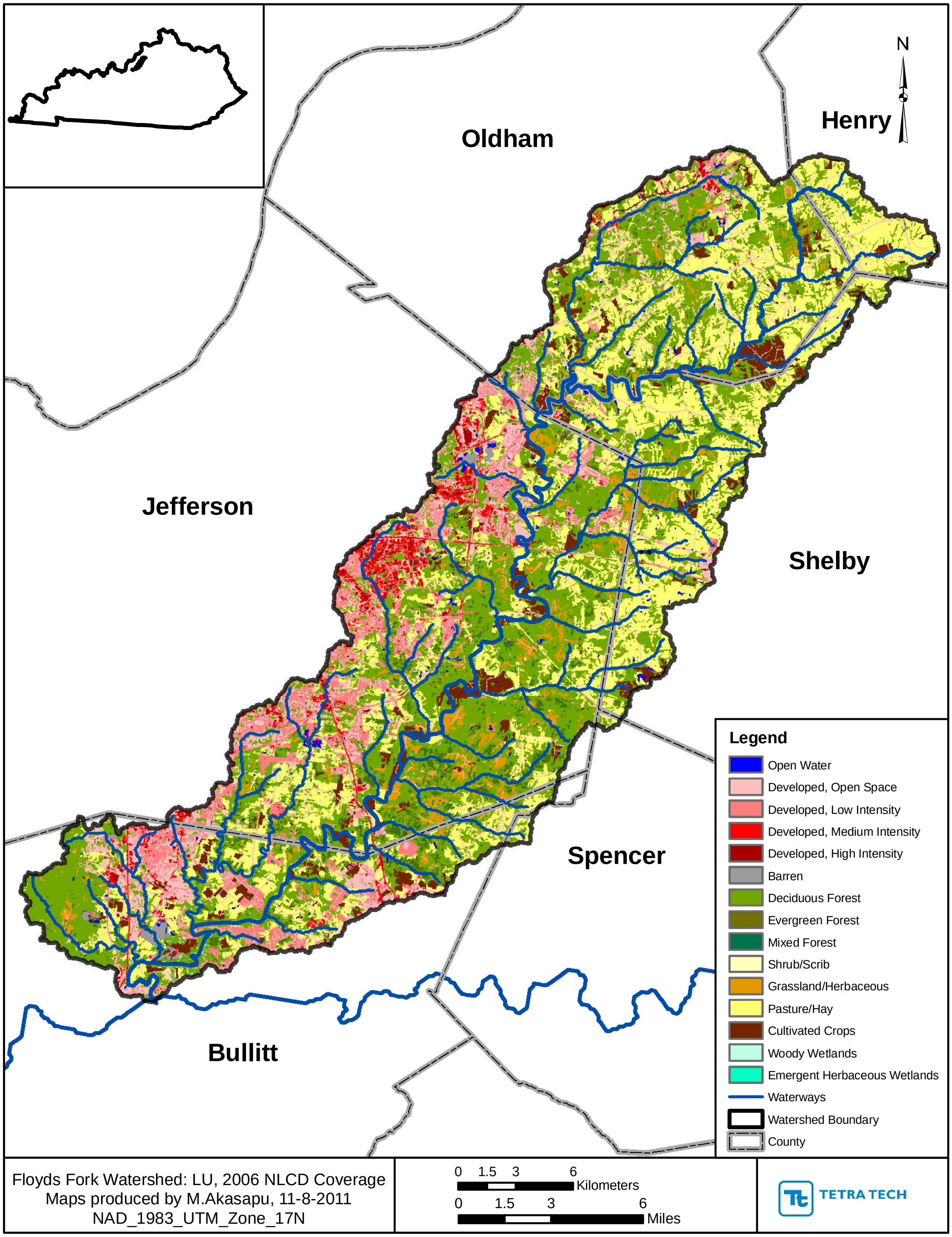


Figure 3-6 NLCD 2006 Coverage of the Floyds Fork Watershed

Table 3-2 Land Use Representation within the Floyds Fork LSPC Model

RMU Land Use Category	RMU Land Use Code	Original NLCD Classification	NLCD Land Use Code	Area (acres)	Area (%)
Water	1	11	Open Water	1089.18	0.60%
LowDevPerv	2	21	Developed, Open space	18320.76	10.06%
LowDevPerv	2	22	Developed, Low Intensity	10531.87	5.78%
MediumDevPerv	3	23	Developed, Medium Intensity	1884.72	1.03%
HighDevPerv	4	24	Developed, High Intensity	237.42	0.13%
Barren	5	31	Barren Land	500.18	0.27%
Forest	6	41	Deciduous Forest	72376.30	39.74%
Forest	6	42	Evergreen Forest	5086.60	2.79%
Forest	6	43	Mixed Forest	478.51	0.26%
Shrub	7	52	Shrub/Scrub	8.01	0.00%
Grassland	8	71	Grassland	6444.07	3.54%
Pasture	9	81	Pasture/Hay	48866.01	26.83%
Crop	10	82	Cultivated Crops	8365.36	4.59%
Wetlands	11	90	Woody Wetlands	879.81	0.48%
Wetlands	11	95	Emergent Herbaceous Wetlands	130.35	0.07%
LowDevImperv	12	222*	21+22, Low Intensity Impervious	2944.30	1.62%
MediumDevImperv	13	232*	23, Medium Intensity Impervious	2045.03	1.12%
HighDevImperv	14	242*	24, High Intensity Impervious	895.06	0.49%
AllOtherImperv	15	332*	Catchall Impervious	379.73	0.21%
FSS	16	888*	Failing Septics	361.53	0.20%
SinkWater	17	990*	Sinkhole Openwater	0.51	0.00%
SinkUrban	18	991*	21+22+23+24 Sinkhole Urban	52.42	0.03%
SinkBarren	19	992*	Sinkhole Barren	0.91	0.00%
SinkForest	20	993*	Sinkhole Forest	89.66	0.05%
SinkGrass	21	994*	Sinkhole Grassland	8.56	0.00%
SinkPasture	22	995*	Sinkhole Pasture	127.56	0.07%
SinkCrop	23	996*	Sinkhole Crop	35.22	0.02%
SinkWet	24	997*	Sinkhole Wetland	0.58	0.00%

* Codes/Classifications added after processing the additional land uses

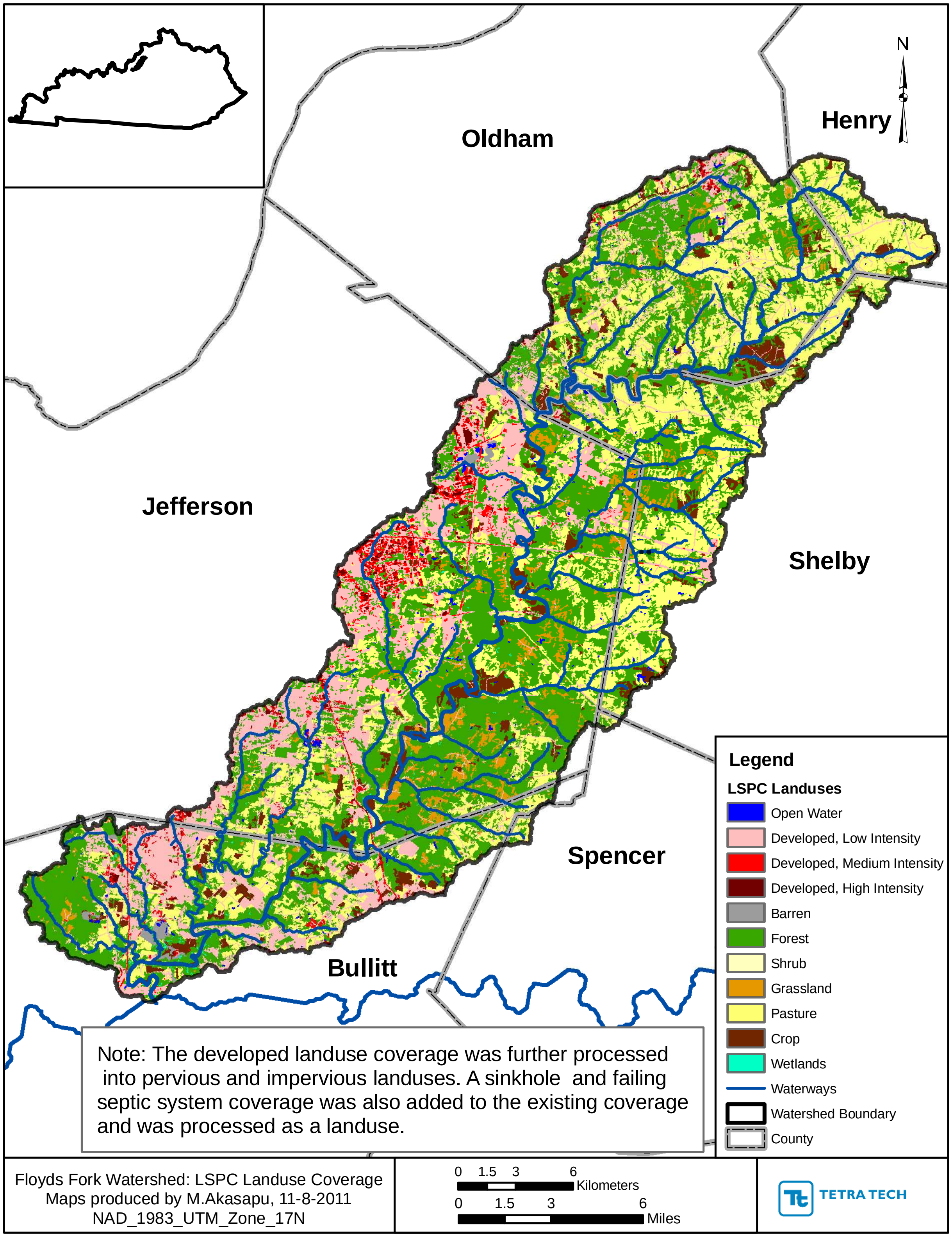


Figure 3-7 LSPC Land use Coverage of the Floyds Fork Watershed showing RMUs

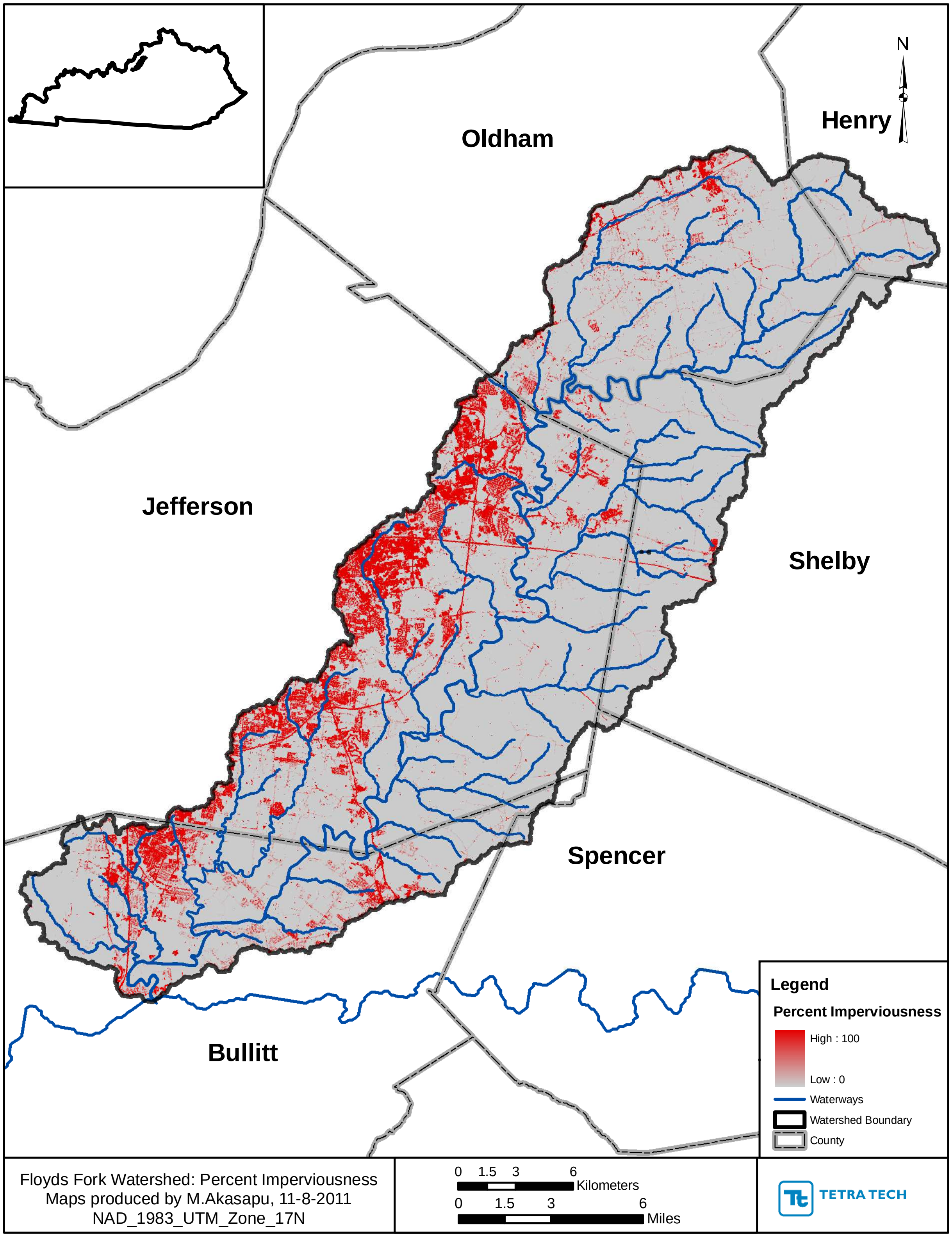


Figure 3-8 NLCD Impervious Coverage of the Floyds Fork Watershed

3.8 Point Source Discharges

Facilities permitted under the National Pollutant Discharge Elimination System (NPDES) are, by definition, considered point sources. There are 73 point source discharges located in the Floyds Fork watershed (Table 3-3 and Figure 3-9). Of the 73 point sources, 6 are Municipal, 20 are Subdivisions, 4 are Schools, 14 are Small Package WWTPs, and 29 are Individual Family residences. Flows and effluent monitoring data for these point source discharges were obtained from both the Kentucky Division of Water (KDOW) and the Environmental Protection Agency's (EPA's) Permit Compliance System (PCS) in the form of Discharge Monitoring Reports (DMR). Data obtained from these reports were input directly into the LSPC model as monthly average time-series data from 2001 to 2010. Nine of the facilities were input into the model as monthly average time-series from 2001 through 2007 and daily time-series from 2008 through 2010 and in some cases from 2007 through 2010.

There were 33 facilities with monthly effluent monitoring data. Of those 33 facilities, all had Ammonia (NH_3) data and 27 facilities had Total Phosphorus (TP) data. In addition there were 4 facilities of the 33 with TP, NH_3, Total suspended solids (TSS) and Dissolved Oxygen (DO) data. Some of the effluent monitoring data contained missing periods or data gaps. For these occurrences, if the gap was less than three months, then an average of the before and after gap value was supplied. If the gap was greater than three months, then the long term monthly average was supplied.

Of the 9 facilities with daily or sub-monthly effluent monitoring data, all had data for TP, NH_3, TSS and Biochemical oxygen demand (BOD_5) and only 3 facilities had DO data. Similar to the monthly average effluent monitoring data in the DMR's, the daily or sub-monthly DMR's also contained missing periods or data gaps. For these occurrences, if the gap was less than three days, then an average of the before and after gap value was supplied. If the gap was greater than three days, then the monthly average for that month was supplied.

Many of the permitted dischargers did not report loads or concentrations for one or more constituents used in the LSPC model. This was especially true for temperature as none of the facilities are required by their permit to report effluent temperatures. The default concentrations/temperatures adopted for the missing constituents are presented in Table 3-5 and Table 3-6. Of the five sets of default concentrations/temperatures developed, two sets were developed for Major (>1 MGD) and Minor (<1 MGD) Municipal facilities, one for Subdivisions/Schools, and the remaining two for Small Package WWTP's and Individual Family Residences. In assigning default concentrations, Subdivisions were treated the same as Schools.

For the Small Sewage facilities (small package WWTP's and individual family residences), KDOW provided all default concentrations/temperatures (Table 3-6). Typical effluent quality published by Metcalf and Eddy (1991) was utilized to estimate the default concentrations for BOD_5 and TSS for all the facilities except the Small Sewage facilities. To develop the default concentrations for Total Nitrogen (TN) and Total Phosphorus (TP) for the remaining facility types (Municipal facilities and Subdivisions/Schools), KDOW first provided assumed influent concentrations for Kentucky's NPDES point sources. The average percent removal of nitrogen and phosphorus (Metcalf & Eddy 1991) for the treatment processes along with the assumed influent concentrations, were utilized to estimate the effluent concentrations for the Municipal facilities and Subdivisions (Table 3-5). This approach helped develop the default concentrations for TN and TP for Municipal facilities and the Subdivisions/Schools. To develop the default concentrations for TN and TP sub-species, the approach as described in the following section (Section 3.8.1) was used.

Table 3-3 Summary of Point Source Discharges to the Floyds Fork Watershed

NPDES Number	Facility Name	Facility Type	Receiving Water	Sub-Watershed	Frequency of Input Data
KY0020001	Lagrange STP	Municipal	Currys Fork/North Fork Currys Fork/UT	213	Monthly
KY0023078	Whispering Oaks MFG Home Comm	Small Package WWTP	Brooks Run/UT/Floyds Fork	116	Monthly
KY0024724	Ash Avenue STP	Subdivision	UT/Floyds Fork	197	Monthly
KY0025194	Jeffersontown WQTC MSD	Municipal	Chenoweth Run (Lower)	165	Daily
KY0026972	Bates Elementary School	Schools	Big Run/UT	151	Constant
KY0029416	Mcneely Lake WQTC MSD	Subdivision	UT/Pennsylvania Run	130	Sub-monthly
KY0029441	Green Valley Apartments	Small Package WWTP	UT/South Fork Currys Fork/Currys Fork	222	Monthly
KY0029459	Chenoweth Hills WQTC MSD	Subdivision	UT/Chenoweth Run (Lower)	162	Sub-monthly
KY0031712	Starview Estates WQTC MSD	Subdivision	Chenoweth Run (Upper)	192	Sub-monthly
KY0031798	Cedar Lake Lodge, Inc.	Small Package WWTP	UT/North Fork Floyds Fork/Floyds Fork	247	Monthly
KY0034151	Hillview Sewer System Plant #1	Subdivision	Cedar Creek/Tanyard Branch	124	Monthly
KY0034169	BCSD Hillview #2	Subdivision	UT/Brooks Run	119	Monthly
KY0034177	BCSD Hillview #3 (Maryville #3)	Subdivision	UT/Brooks Run	119	Monthly
KY0034185	Pioneer Village Sewer Plant #1	Subdivision	Brooks Run	115	Monthly
KY0034801	BCSD Bullitt Hills Subdivision	Subdivision	UT/Tanyard Branch	124	Monthly
KY0036501	Berrytown WQTC MSD	Subdivision	UT/Chenoweth Run (Upper)	192	Sub-monthly
KY0038610	Hunters Hollow Subd	Subdivision	Brooks Run	119	Monthly
KY0039004	KJC Institute for Women	Small Package WWTP	Floyds Fork	198	Monthly
KY0039870	Lakewood Valley Subd STP	Subdivision	UT/South Fork Currys Fork/Currys Fork	220	Constant
KY0040193	Overdale Elementary School	Schools	Tanyard Branch/ Cedar Creek/ Floyds Fork	124	Constant
KY0042153	Cedar Ridge Camp, Inc.	Small Package WWTP	UT/Floyds Fork	172	Monthly
KY0042226	Chenoweth Run WQTC	Subdivision	UT/Chenoweth Run (Upper)	191	Sub-monthly
KY0044342	Lake Of The Woods WQTC MSD	Subdivision	UT/Chenoweth Run (Lower)	162	Sub-monthly
KY0054674	Lockwood Estates Subd STP	Subdivision	South Fork Currys Fork/ Currys Fork	211	Monthly
KY0060577	Country Village STP	Subdivision	UT/Currys Fork	207	Monthly
KY0069485	Friendship Manor	Small Package WWTP	UT/Floyds Fork	196	Monthly
KY0072168	Big Valley MHP	Small Package WWTP	Bluelick Creek	106	Monthly
KY0073059	Camp Shantituck Girl Scout CMP	Small Package WWTP	Cedar Creek	122	Constant
KY0076732	Centerfield Elementary School	Schools	Currys Fork/South Fork Currys Fork	211	Constant
KY0076741	Cherrytree Apartments	Small Package WWTP	Floyds Fork	199	Constant
KY0077666	The Crossings Golf Club	Small Package WWTP	Brooks Run	117	Constant
KY0077674	Lake Columbia Subdivision	Subdivision	Cedar Creek/UT	133	Constant
KY0086843	Middletown Industrial Park	Small Package WWTP	Chenoweth Run (Upper)	191	Monthly
KY0090956	Persimmon Ridge Phase 14	Subdivision	Floyds Fork	228	Monthly
KY0094307	BCSD Willabrook Sanitation	Subdivision	Brooks Run	116	Monthly
KY0098540	Cedar Creek WQTC MSD	Municipal	Cedar Creek	135	Daily
KY0100994	Bullitt Co BD of ED	Schools	Brooks Run/UT	114	Monthly
KY0101419	Kingswood Subd	Subdivision	Broad Run	293	Constant
KY0101885	Riedling Building	Small Package WWTP	Tanyard Branch	124	Monthly
KY0102784	Floyds Fork WQTC MSD	Municipal	Floyds Fork	185	Daily
KY0102873	Brooks Mobile Home & RV Park	Small Package WWTP	Brooks Run	116	Monthly
KY0103110	Buckner STP	Municipal	UT/North Fork Currys Fork	210	Monthly
KY0103900	Hillview STP	Municipal	UT/Brooks Run/Floyds Fork	116	Monthly
KY0105384	Advanced Child Care West	Small Package WWTP	Ditch/UT/Floyds Fork	203	Monthly
KYG400010	Edaward A Zuercher Jr. Residence	Individual Family Residence	Back Run	293	Constant
KYG400028	Anthony T Aulbach Residence	Individual Family Residence	Pope Lick/UT	178	Constant
KYG400032	Melvin & Shirley Williams Residence	Individual Family Residence	Cedar Creek	137	Constant
KYG400082	Reed Wilcox Residence	Individual Family Residence	Floyds Fork/UT	199	Constant
KYG400105	Maria E McCarson Residence	Individual Family Residence	North Fork Currys Fork	210	Constant
KYG400112	Charles G Parrot Residence	Individual Family Residence	North Fork Currys Fork	212	Constant
KYG400128	Kamal Fathaltzadeh Residence	Individual Family Residence	Long Run/UT	259	Constant
KYG400137	Raymond R Peters Sr. Residence	Individual Family Residence	Pennsylvania Run	132	Constant
KYG400139	Ernest & Patricia Entin Residence	Individual Family Residence	Cedar Creek/UT	134	Constant
KYG400147	Ebbs Residence	Individual Family Residence	Currys Fork/Floyds Fork	207	Constant
KYG400150	Robert & Mary Miller Residence	Individual Family Residence	Chenoweth Run (Lower)	162	Constant
KYG400153	Victor J Diorio Jr. Residence	Individual Family Residence	Floyds Fork	174	Constant
KYG400161	Mckee Residence	Individual Family Residence	Razor Branch	163	Constant
KYG400166	James L Shipp Residence	Individual Family Residence	Cedar Creek	134	Constant
KYG400177	William E Berryman Residence	Individual Family Residence	Cedar Creek	137	Constant
KYG400189	Susan Weis Residence	Individual Family Residence	Brush Run	171	Constant
KYG400194	Ken & Alice Weber Residence	Individual Family Residence	Pope Lick	178	Constant
KYG400235	Steven & Cheryl Powers Residence	Individual Family Residence	Floyds Fork/UT	195	Constant
KYG400250	Joe and Pam Brooks Residence	Individual Family Residence	Long Run/UT	259	Constant
KYG400251	Marguerite R Weber Residence	Individual Family Residence	Chenoweth Run (Lower)	162	Constant
KYG400259	Dennis & Sherry Ballard Residence	Individual Family Residence	Floyds Fork/ UT	174	Constant
KYG400289	Patricia H Gibson Residence	Individual Family Residence	South Fork Currys Fork	211	Constant
KYG400329	Larry & Angelyn Carlisle Residence	Individual Family Residence	Brooks Run/UT	116	Constant
KYG400403	Chris Freundenburger Residence	Individual Family Residence	Sheckels Run	285	Constant
KYG400420	Melvin Seals Residence	Individual Family Residence	Bluelick Creek	106	Constant
KYG400613	Brad Murrell Residence	Individual Family Residence	Floyds Fork/UT	189	Constant
KYG401875	Wood Residence	Individual Family Residence	Wells Run	141	Constant
KYG401905	Fladung Residence	Individual Family Residence	Broad Run	298	Constant
KYG402142	Carpenter Residence	Individual Family Residence	Pope Lick	174	Constant

3.8.1 Nutrient Speciation

The default concentrations for the nitrogen and phosphorus sub-species were computed using the ratios developed from the in-stream monitoring data. Based on the location of the in-stream monitoring sites, three sets of ratios were developed, two for Municipal facilities and one for Subdivisions/Schools as shown below. These ratios were used to determine the TN and TP sub-species default concentrations as listed in Table 3-5.

For minor point source discharges (Municipal facilities <1 MGD), the phosphorus and nitrogen sub-species were calculated using the in-stream ratios shown below.

Organic Phosphorus = Total Phosphorous * 0.43

Orthophosphate = Total Phosphorous * 0.57

Ammonia = Total Nitrogen * 0.02

Nitrite-Nitrate = Total Nitrogen * 0.78

Organic Nitrogen = Total Nitrogen * 0.20

For major point source discharges (Municipal facilities >1 MGD), the phosphorus and nitrogen sub-species were calculated using the in-stream ratios shown below.

Organic Phosphorus = Total Phosphorous * 0.55

Orthophosphate = Total Phosphorous * 0.45

Ammonia = Total Nitrogen * 0.03

Nitrite-Nitrate = Total Nitrogen * 0.86

Organic Nitrogen = Total Nitrogen * 0.11

For Subdivisions/Schools, the phosphorus and nitrogen sub-species were calculated using the in-stream ratios shown below.

Organic Phosphorus = Total Phosphorous * 0.42

Orthophosphate = Total Phosphorous * 0.58

Ammonia = Total Nitrogen * 0.02

Nitrite-Nitrate = Total Nitrogen * 0.78

Organic Nitrogen = Total Nitrogen * 0.20

KDOW provided additional TP, NH_3 and TKN (Total Kjehdahl Nitrogen) data for 9 facilities, of which 5 were used to calculate the individual nitrogen and phosphorus species for those facilities. There was one facility under the subdivision/school category with speciation ratios. The nitrogen and phosphorus species were quantified using these ratios for the remaining 6 facilities under this category with sub-monthly data. However, for McNeely Lake WQTC MSD (KY00296416, Subdivision/School), speciation ratios for City of Lagrange (KY0020001, < 1 MGD, Municipal) were provided for better representation of the data with respect to the measured data. Table 3-4 shows the nutrient speciation ratios used in the model for the 5 facilities with daily/sub-monthly data.

Table 3-4 Nutrient speciation ratios used for the facilities with daily/sub-monthly data

NPDES Number	NPDES Name	Design Flow, MGD	Type of Facility	Speciation Ratios				
				NH_3	NO_X	ORGN	PO_4	ORGP
KY0020001	City of Lagrange	0.8	Municipal (<1 MGD)	0.1	0.8	0.1	0.7	0.3
KY0025194	Jeffersontown WQTC MSD	4.0	Municipal (>1 MGD)	0.1	0.8	0.1	0.3	0.7
KY0034151	Hillview # 1 Outfall	0.2	Subdivision/School	0.4	0.2	0.4	0.9	0.1
KY0098540	MSD Cedar Creek WQTC	7.5	Municipal (>1 MGD)	0.1	0.8	0.1	0.2	0.8
KY0102784	MSD Floyds Fork WQTC	3.3	Municipal (>1 MGD)	0.1	0.8	0.1	0.8	0.2

3.8.2 Assigning Default concentrations

If the point source discharge did not have any measured phosphorus data, then the default concentrations for TP and its sub-species (Organic Phosphorus and Orthophosphate) were applied from tables 3-5 and 3-6, depending on the facility type. For facilities with measured TP data, the sub-species concentrations were calculated using the ratios shown in Section 3.8.1 for the respective facility type.

If the point source discharge did not have any measured nitrogen data, then the default concentrations for TN and its sub-species (Ammonia, Nitrate+Nitrite, and Organic Nitrogen) were applied from tables 3-5 and 3-6, depending on the facility type. For facilities with measured NH_3 data, the default concentrations shown in tables 3-5 and 3-6 were applied for Nitrate+Nitrite and Organic Nitrogen. All the concentrations from the nitrogen sub-species were then summed to get the TN concentration. For facilities with daily/sub-monthly measured NH_3 data, Nitrate+Nitrite and Organic Nitrogen concentrations were calculated by first determining the assumed Total Nitrogen concentration using the NH_3 to TN ratio (Section 3.8.1), then multiplying the TN by the ratios for Nitrate+Nitrite and Organic Nitrogen for the respective facility type.

Table 3-5 Assumed Water Quality Concentrations for Municipal facilities/ Subdivisions/ Schools without Data

Parameter ID	Name	Assumed concentrations/ Temperature		
		Minor (<1 MGD)	Major (>1 MGD)	Subdivisions/ Schools
TP*	Total Phosphorus	2.3	1.0	1.2
PO4**	Orthophosphate	1.3	0.5	0.7
OrgP**	Organic Phosphorus	1.0	0.5	0.5
TN*	Total Nitrogen	17.0	10.0	8.0
NH3**	Ammonia	0.4	0.3	0.2
Nox**	Nitrite-Nitrate	13.3	8.6	6.3
OrgN**	Organic Nitrogen	3.3	1.1	1.6
BOD_5	5-day Biochemical Oxygen Demand	10.0	5.0	10.0
DO	Dissolved Oxygen	5.0	5.0	5.0
TSS	Total Suspended solids	20.0	20.0	20.0
Chlorophyll-a	Chlorophyll-a	0.0	0.0	0.0
WTEMP	Water Temperature	15° C October through March 25° C April through	15° C October through March 25° C April through	15° C October through March 25° C April through

* Determined using KDOW's assumed influent concentrations and Metcalf & Eddy's average percent removal of TN and TP.

** Calculated using the TN and TP concentrations from the table and the ratios from section 3.8.1

Table 3-6 Assumed Water Quality Concentrations for Small Sewage facilities without Data

Parameter ID	Name	Assumed concentrations/ Temperature	
		Small Package WWTP's	Individual Family Residences
TP	Total Phosphorus	4.0	4.0
PO4	Orthophosphate	3.0	3.0
OrgP	Organic Phosphorus	1.0	1.0
TN	Total Nitrogen	20.0	20.0
NH3	Ammonia	12.0	14.0
NOx	Nitrite-Nitrate	0.0	0.0
OrgN	Organic Nitrogen	8.0	6.0
BOD_5	5-day Biochemical Oxygen Demand	10.0	27.0
DO	Dissolved Oxygen	5.0	7.0
TSS	Total Suspended solids	30.0	29.0
Chlorophyll-a	Chlorophyll-a	0.0	0.0
WTEMP	Water Temperature	15° C October through March 25° C April through September	15° C October through March 25° C April through September

3.8.3 Adjustments to Default Concentrations

During the calibration it was observed that at a couple stations, the default concentrations that were applied were affecting the results. This mainly occurred at water quality stations that were highly dominated by point source loading for which the point source did not have measured DMR data. To improve the calibration, the default concentrations for those facilities were changed accordingly.

The TN calibration on North Fork Currys Fork was affected by the assumed default concentrations for TN species. The simulated results for TN concentrations at North Fork Currys Fork were lower in magnitude (5-10 mg/L) compared to the measured concentrations of 20-30 mg/L. Among the four point source discharges upstream of the station, the two with the highest design flows (KY0020001 and KY0103110) have the most impact. With the DMR's available for NH_3, the default concentrations for NO_X and ORGN were changed to better capture the appropriate magnitude. For KY0020001, the default concentration for NO_X was changed from 13.3 mg/L to 19.5 mg/L and for KY0103110, it was changed to 25 mg/L. Similarly, the default concentrations for ORGN were changed from 3.3 mg/L to 4.8 mg/L for KY0020001 and to 10 mg/L for KY0103110. Results were greatly improved with the adjusted default values which were reflected with simulated TN results in the range of 15-20 mg/L. The remaining facilities were assigned the defaults as mentioned in Table 3-7.

Similarly, for the TP calibration on an unnamed tributary (UT) to South Fork Currys Fork, the assumed default concentration for TP was affecting the results at USGS station 03297850. The simulated concentrations were not capturing the peaks of the measured data. Measured TP concentrations range up to 3.5 mg/L at USGS station 03297850, therefore, the default concentration for TP was increased from 2 to 2.5 mg/L for facility KY0039870 to improve the results. Tables 3-7 and 3-8 summarize the flows and default water quality concentrations assigned to all of the point source discharges.

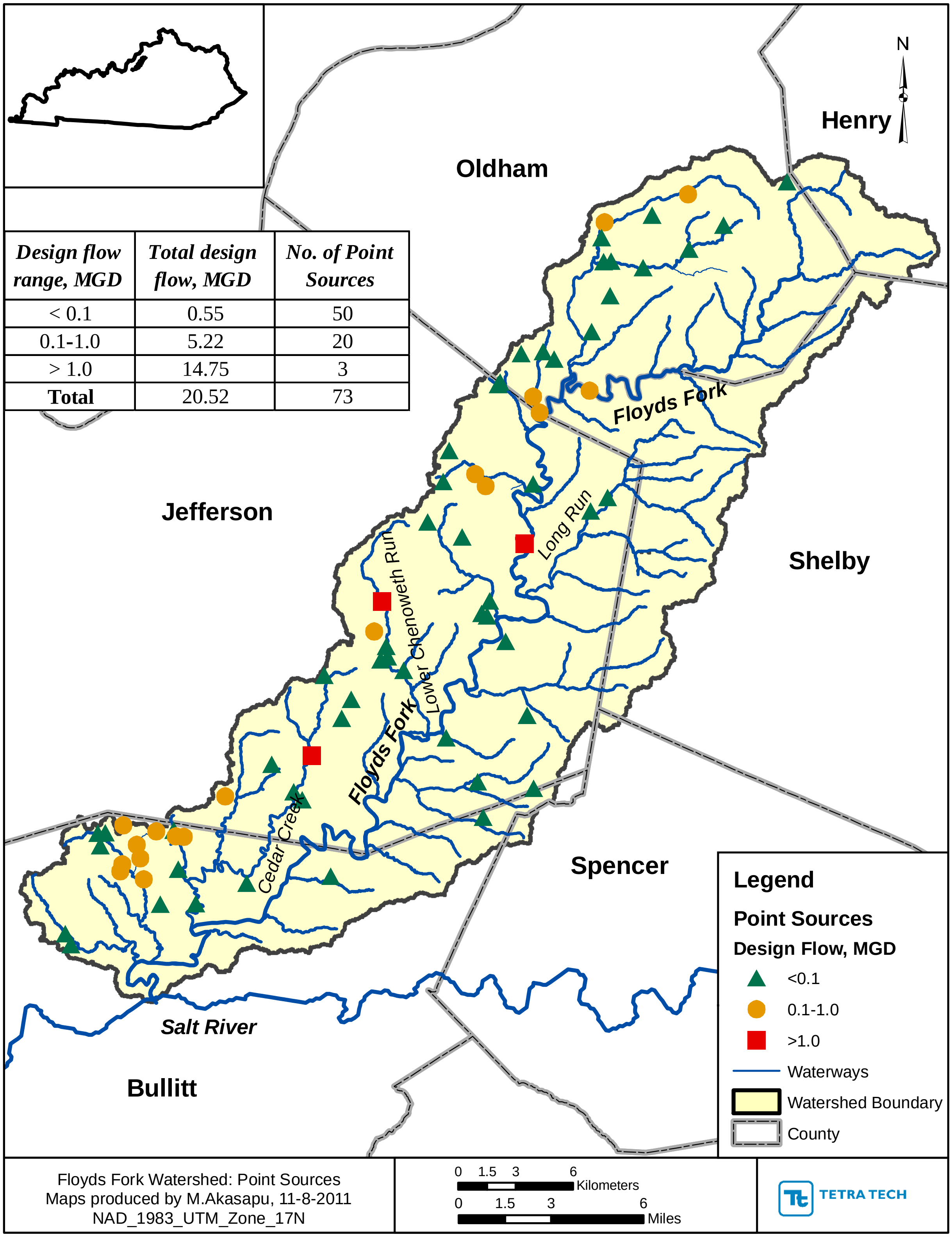
Table 3-7 Assumed Flows for all Point Source Discharges

NPDES Number	Facility Type	Design Flow, MGD	Flow used
KY0020001	Municipal	0.7750	DMR
KY0023078	Small Package WWTP	0.1250	DMR
KY0024724	Subdivision	0.3000	DMR
KY0025194	Municipal	4.0000	DMR
KY0026972	Schools	0.0130	Design Flow
KY0029416	Subdivision	0.2050	DMR
KY0029441	Small Package WWTP	0.0300	DMR
KY0029459	Subdivision	0.2000	DMR
KY0031712	Subdivision	0.1000	DMR
KY0031798	Small Package WWTP	0.0200	DMR
KY0034151	Subdivision	0.2310	DMR
KY0034169	Subdivision	0.3170	DMR
KY0034177	Subdivision	0.1480	DMR
KY0034185	Subdivision	0.3100	DMR
KY0034801	Subdivision	0.3500	DMR
KY0036501	Subdivision	0.0750	Design Flow
KY0038610	Subdivision	0.2400	DMR
KY0039004	Small Package WWTP	0.1250	DMR
KY0039870	Subdivision	0.1000	Design Flow
KY0040193	Schools	0.0100	Design Flow
KY0042153	Small Package WWTP	0.0050	DMR
KY0042226	Subdivision	0.4700	DMR
KY0044342	Subdivision	0.0440	DMR
KY0054674	Subdivision	0.0450	DMR
KY0060577	Subdivision	0.0600	DMR
KY0069485	Small Package WWTP	0.0170	DMR
KY0072168	Small Package WWTP	0.0700	DMR
KY0073059	Small Package WWTP	0.0100	Design Flow
KY0076732	Schools	0.0100	Design Flow
KY0076741	Small Package WWTP	0.0075	Design Flow
KY0077666	Small Package WWTP	0.0050	DMR
KY0077674	Subdivision	0.0120	Design Flow
KY0086843	Small Package WWTP	0.1600	DMR
KY0090956	Subdivision	0.1420	DMR
KY0094307	Subdivision	0.1200	DMR
KY0098540	Municipal	7.5000	DMR
KY0100994	Schools	0.0430	DMR
KY0101419	Subdivision	0.0400	Design Flow
KY0101885	Small Package WWTP	0.0005	DMR
KY0102784	Municipal	3.2500	DMR
KY0102873	Small Package WWTP	0.0150	DMR
KY0103110	Municipal	0.1350	DMR
KY0103900	Municipal	0.1500	DMR
KY0105384	Small Package WWTP	0.0006	DMR
KYG400010	Individual Family Residence	0.0008	Design Flow
KYG400028	Individual Family Residence	0.0005	Design Flow
KYG400032	Individual Family Residence	0.0008	Design Flow
KYG400082	Individual Family Residence	0.0005	Design Flow
KYG400105	Individual Family Residence	0.0005	Design Flow
KYG400112	Individual Family Residence	0.0004	Design Flow
KYG400128	Individual Family Residence	0.0005	Design Flow
KYG400137	Individual Family Residence	0.0008	Design Flow
KYG400139	Individual Family Residence	0.0010	Design Flow
KYG400147	Individual Family Residence	0.0004	Design Flow
KYG400150	Individual Family Residence	0.0007	Design Flow
KYG400153	Individual Family Residence	0.0008	Design Flow
KYG400161	Individual Family Residence	0.0008	Design Flow
KYG400166	Individual Family Residence	0.0010	Design Flow
KYG400177	Individual Family Residence	0.0004	Design Flow
KYG400189	Individual Family Residence	0.0008	Design Flow
KYG400194	Individual Family Residence	0.0010	Design Flow
KYG400235	Individual Family Residence	0.0010	Design Flow
KYG400250	Individual Family Residence	0.0004	Design Flow
KYG400251	Individual Family Residence	0.0007	Design Flow
KYG400259	Individual Family Residence	0.0008	Design Flow
KYG400289	Individual Family Residence	0.0004	Design Flow
KYG400329	Individual Family Residence	0.0013	Design Flow
KYG400403	Individual Family Residence	0.0005	Design Flow
KYG400420	Individual Family Residence	0.0004	Design Flow
KYG400613	Individual Family Residence	0.0005	Design Flow
KYG401875	Individual Family Residence	0.0005	Design Flow
KYG401905	Individual Family Residence	0.0005	Design Flow
KYG402142	Individual Family Residence	0.0005	Design Flow

Table 3-8 Assumed Water Quality Concentrations for all Point Source Discharges

NPDES Number	Defaults/DMR concentrations, mg/L										
	TSS	Chlorophyll-a	BOD5	DO	TP	PO4	Organic P	TN	NH3	NOX	Organic N
KY0020001	DMR	Default	Default	DMR		Calculated		Sum	DMR	19.5	4.8
KY0023078	Default	Default	Default	Default	DMR	Calculated		Sum	DMR	Default	
KY0024724	Default	Default	Default	Default	DMR	Calculated		Sum	DMR	Default	
KY0025194	DMR	Default	DMR			Calculated		Calculated	DMR	Calculated	
KY0026972	Default	Default	Default	Default	Default			Default			
KY0029416	DMR	Default	DMR	Default	DMR	Calculated		Sum	DMR	Calculated	
KY0029441	20.0	Default	Default	Default	2.0	1.5	0.5	Sum	DMR	Default	2.0
KY0029459	DMR	Default	DMR	Default	DMR	Calculated		Calculated	DMR	Calculated	
KY0031712	DMR	Default	DMR	Default	DMR	Calculated		Calculated	DMR	Calculated	
KY0031798	Default	Default	Default	Default	DMR	Calculated		Sum	DMR	Default	
KY0034151	Default	Default	Default	Default	DMR	Calculated		DMR		Calculated	
KY0034169	Default	Default	Default	Default	DMR	Calculated		Sum	DMR	Default	
KY0034177	Default	Default	Default	Default	DMR	Calculated		Sum	DMR	Default	
KY0034185	Default	Default	Default	Default	Default			Sum	DMR	Default	
KY0034801	Default	Default	Default	Default	DMR	Calculated		Sum	DMR	Default	
KY0036501	DMR	Default	DMR	Default	DMR	Calculated		Calculated	DMR	Calculated	
KY0038610	Default	Default	Default	Default	DMR	Calculated		Sum	DMR	Default	
KY0039004	Default	Default	Default	Default	DMR	Calculated		Sum	DMR	Default	
KY0039870	Default	Default	Default	Default	2.5	1.4	1.1	Default			
KY0040193	Default	Default	Default	Default	Default			Default			
KY0042153	Default	Default	Default	Default	DMR	Calculated		Sum	DMR	Default	
KY0042226	DMR	Default	DMR	Default	DMR	Calculated		Calculated	DMR	Calculated	
KY0044342	DMR	Default	DMR	Default	DMR	Calculated		Calculated	DMR	Calculated	
KY0054674	Default	Default	Default	Default	DMR	Calculated		Sum	DMR	8.5	1.7
KY0060577	Default	Default	Default	Default	DMR	Calculated		Sum	DMR	Default	
KY0069485	Default	Default	Default	Default	DMR	Calculated		Sum	DMR	Default	
KY0072168	Default	Default	Default	Default	Default			Sum	DMR	Default	
KY0073059	Default	Default	Default	Default	Default			Default			
KY0076732	Default	Default	Default	Default	Default			Default			
KY0076741	Default	Default	Default	Default	Default			Default			
KY0077666	Default	Default	Default	Default	Default			Sum	DMR	Default	
KY0077674	Default	Default	Default	Default	Default			Default			
KY0086843	Default	Default	Default	Default	Default			Sum	DMR	Default	
KY0090956	Default	Default	Default	Default	DMR	Calculated		Sum	DMR	Default	
KY0094307	Default	Default	Default	Default	DMR	Calculated		Sum	DMR	Default	
KY0098540	DMR	Default	5.0	Default	DMR	Calculated		Calculated	DMR	Calculated	
KY0100994	Default	Default	Default	Default	Default			Sum	DMR	Default	
KY0101419	Default	Default	Default	Default	Default			Default			
KY0101885	Default	Default	Default	Default	DMR	Calculated		Sum	DMR	Default	
KY0102784	DMR	Default	DMR			Calculated		Calculated	DMR	Calculated	
KY0102873	Default	Default	Default	Default	DMR	Calculated		Sum	DMR	Default	
KY0103110	Default	Default	Default	Default	DMR	Calculated		Sum	DMR	25.0	10.0
KY0103900	Default	Default	Default	Default	DMR	Calculated		Sum	DMR	Default	
KY0105384	Default	Default	Default	Default	Default			Sum	DMR	Default	
KYG400010	Default	Default	Default	Default	Default			Default			
KYG400028	Default	Default	Default	Default	2.0	1.5	0.5	5.0	3.5	0.0	1.5
KYG400032	Default	Default	Default	Default	Default			Default			
KYG400082	Default	Default	Default	Default	Default			Default			
KYG400105	Default	Default	Default	Default	Default			Default			
KYG400112	Default	Default	Default	Default	Default			Default			
KYG400128	Default	Default	Default	Default	Default			Default			
KYG400137	Default	Default	Default	Default	Default			Default			
KYG400139	Default	Default	Default	Default	Default			Default			
KYG400147	Default	Default	Default	Default	Default			Default			
KYG400150	Default	Default	Default	Default	Default			Default			
KYG400153	Default	Default	Default	Default	2.0	1.5	0.5	10.0	7.0	0.0	3.0
KYG400161	Default	Default	Default	Default	Default			Default			
KYG400166	Default	Default	Default	Default	Default			Default			
KYG400177	Default	Default	Default	Default	Default			Default			
KYG400189	Default	Default	Default	Default	Default			Default			
KYG400194	Default	Default	Default	Default	2.0	1.5	0.5	5.0	3.5	0.0	1.5
KYG400235	Default	Default	Default	Default	Default			Default			
KYG400250	Default	Default	Default	Default	Default			Default			
KYG400251	Default	Default	Default	Default	Default			Default			
KYG400259	Default	Default	Default	Default	2.0	1.5	0.5	10.0	7.0	0.0	3.0
KYG400289	Default	Default	Default	Default	Default			Default			
KYG400329	Default	Default	Default	Default	Default			Default			
KYG400403	Default	Default	Default	Default	Default			Default			
KYG400420	Default	Default	Default	Default	Default			Default			
KYG400613	Default	Default	Default	Default	Default			Default			
KYG401875	Default	Default	Default	Default	Default			Default			
KYG401905	Default	Default	Default	Default	Default			Default			
KYG402142	Default	Default	Default	Default	2.0	1.5	0.5	10.0	7.0	0.0	3.0

Calculated = Water Quality concentrations calculated using the ratios mentioned in Section 3.8.1 and Table 3-6
Default = Water Quality concentrations as mentioned in the Tables 3-4 and 3-5
Sum = Sum of the Nitrogen species



Design flow range, MGD	*Total design flow, MGD*	*No. of Point Sources*
< 0.1	0.55	50
0.1-1.0	5.22	20
> 1.0	14.75	3
Total	20.52	73

Figure 3-9 Permitted Discharges to the Floyds Fork Watershed

3.9 Sanitary Sewer Overflows

Sanitary Sewer Overflows (SSOs) are occasional, yet unintentional discharges of raw sewage from municipal sanitary sewers. Apart from SSOs, Combined Sewer Overflows (CSOs) contain stormwater in addition to untreated human and industrial waste. The untreated sewage from these discharges has a high risk of contaminating the waters causing serious water quality problems (EPA, 2011). Data on CSOs/SSOs for the Floyds Fork watershed model was obtained from the Kentucky Pollutant Discharge Elimination system's (KPDES) DMR and the incident and facility reports on Sanitary Sewer Overflows. The data was validated by the Water Quality Treatment Center Reports posted on MSD's Project WIN website (www.msdlouky.org/projectwin/). Project WIN is MSD's program to respond to the Federal Consent Decree to resolve violations of the Clean Water Act for untreated overflows from MSD's separate and combined sewer systems.

According to the CSOs/SSOs overflow locations published on Project WIN, there were no CSO's in the Floyds Fork watershed. However, SSOs from 27 NPDES facilities were reported for their respective WQTC permit (Table 3-10 and Figure 3-10). These unintentional discharges were caused mainly by a lack of system capacity, storm flows, structural failures and in some cases, bypasses at the treatment centers.

The reported discharge amount for the SSOs was utilized to develop flow time-series inputs on a daily scale. To develop daily time-series inputs for loads, published concentrations for typical composition of untreated domestic wastewater of medium or weak strength was used based on the impact observed at the facilities (Table 3-9) (Metcalf & Eddy, 1991). Flows and loads for the SSO's were only developed for the days with data (i.e., only when SSO's occurred). It was assumed that for all other days, there were no SSO's, so the flow and loads were zero.

Table 3-9 Assumed Water Quality Concentrations for SSOs

Parameter ID	Name	Assumed concentrations/ Temperatures		
		Strong	Medium	Weak
TP	Total Phosphorus	15.0	8.0	4.0
PO4	Orthophosphate	10.0	5.0	3.0
OrgP	Organic Phosphorus	5.0	3.0	1.0
TN	Total Nitrogen	85.0	40.0	20.0
NH3	Ammonia	50.0	25.0	12.0
NOx	Nitrite-Nitrate	0.0	0.0	0.0
OrgN	Organic Nitrogen	35.0	15.0	8.0
BOD_5	5-day Biochemical Oxygen Demand	400.0	220.0	110.0
DO	Dissolved Oxygen	10.0	10.0	10.0
TSS	Total Suspended solids	350.0	220.0	100.0
Chlorophyll-a	Chlorophyll-a	0.0	0.0	0.0
WTEMP	Water Temperature	15° C October through March 25° C April	15° C October through March 25° C April	15° C October through March 25° C April

Table 3-10 Data on SSOs

Source: Incident and Facility reports			
NPDES Point Source	**No. of events recorded**	**No. of events quantified**	**Range of Dates**
KY0020001	93	26	12/18/2002-11/26/2010
KY0023078	1	0	6/1/2003
KY0024724	87	19	1/2/2003-10/2/2009
KY0025194	140	70	7/9/2003-12/10/2010
KY0029416	4	4	5/2/2008-7/22/2010
KY0029441	17	8	2/21/2003-9/9/2009
KY0029459	21	19	3/31/2004-12/8/2010
KY0031712	10	6	9/8/2003-5/2/2010
KY0034151	9	2	8/20/2003-12/12/2010
KY0034169	10	2	1/25/2005-9/14/2008
KY0034177	7	2	5/26/2006-9/14/2008
KY0034185	24	6	5/9/2005-10/9/2009
KY0034801	15	0	2/23/2003-6/23/2008
KY0036501	9	5	1/2/2003-5/2/2010
KY0038610	90	51	4/18/2003-11/30/2010
KY0039004	4	2	9/14/2008-2/19/2010
KY0039870	7	5	11/12/2003-7/29/2009
KY0042153	3	0	5/23/2003-9/20/2007
KY0042226	13	13	6/13/2003-10/12/2010
KY0044342	1	0	8/24/2007
KY0054674	14	7	1/16/2004-9/27/2009
KY0060577	20	7	2/21/2003-7/9/2009
KY0069485	5	2	5/23/2007-7/10/2008
KY0077674	8	5	1/1/2003-5/6/2010
KY0086843	6	2	7/28/2003-7/21/2010
KY0090956	4	0	3/4/2008-11/29/2010
KY0094307	3	1	2/1/2003-9/14/2008
KY0098540	64	49	1/2/2003-11/16/2010
KY0100994	4	0	1/10/2003
KY0101419	12	6	5/20/2003-11/26/2010
KY0102784	26	18	5/5/2003-11/19/2010
KY0103110	96	91	8/25/2003-10/28/2009
KY0103900	25	2	9/2/2003-9/19/2010
Source: DMR			
NPDES Point Source	**No. of events recorded**	**No. of events quantified**	**Range of Dates**
KY0025194	-	155	1/2/2005-12/10/2010
KY0029416	-	4	5/3/2008-7/22/2010
KY0029459	-	17	4/4/2008-12/8/2010
KY0031712	-	5	1/24/2008-5/2/2010
KY0036501	-	5	3/13/2006-5/2/2010
KY0039004	-	0	-
KY0042226	-	20	1/1/2005-10/12/2010
KY0044342	-	0	-
KY0098540	-	47	1/4/2005-11/16/2010
KY0102784	-	16	3/9/2005-11/19/2010

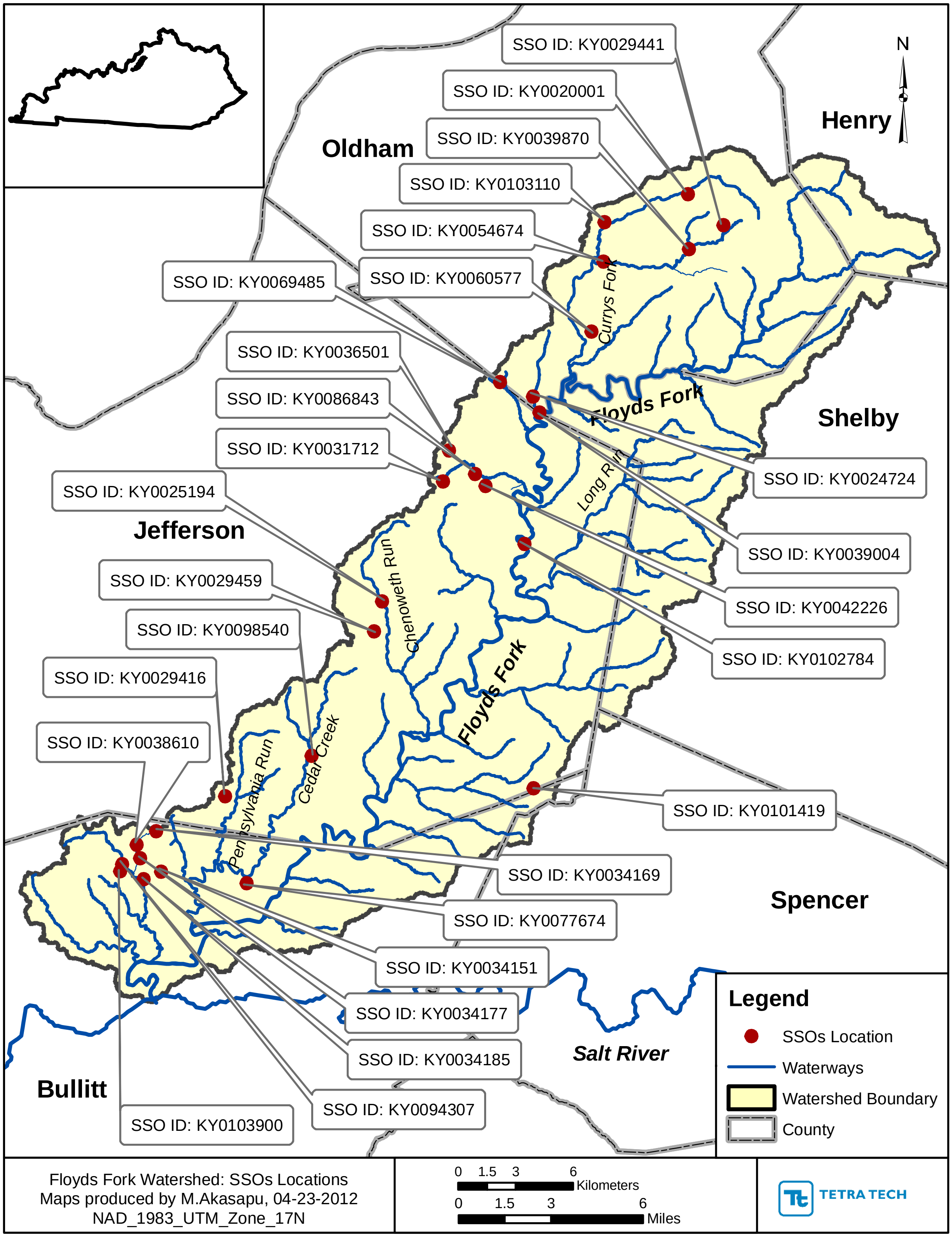


Figure 3-10 SSOs identified in the Floyds Fork Watershed

3.10 Industrial Water Withdrawals

There are 11 industrial water withdrawals located in the Floyds Fork watershed that were represented in the LSPC watershed model (Table 3-11). Monthly average water withdrawal data were obtained from KDOW. For security purposes, the locations of the water withdrawals cannot be disclosed.

Table 3-11 Summary of Industrial Withdrawal in the Floyds Fork Watershed

Withdrawal Name	Permit Number	Source Water	Sub-Watershed	Monthly Permitted Withdrawal	
				Month	Limit (MGD)
KY Solite Corp	0987	Large reservoir south of Brooks Run	107	October - March	0.202
				April - September	0.310
Persimmon Ridge Subdivision	1020	Irrigation lake#1	228	October - April	0.000
				May - September	0.300
Persimmon Ridge Subdivision	1090	Irrigation lake#1	228	November - February	0.000
				March - October	0.300
Quail Chase Golf Club	1093	McNeely lake, an impoundment of Pennsylvania Run	131	December - March	0.000
				April and November	1.000
				May - October	1.250
Polo Fileds Golf Course	1257	Polo fields Lake, an impoundment of Brush Run	187	November - March	0.000
				April and October	0.250
				May - September	0.500
Polo Fileds Golf Course	1258	Polo fields Lake, an impoundment of Brush Run	187	November - March	0.000
				April and October	0.250
				May - September	0.500
Action Landscape, Inc.	1264	RM 4.3 OF Chenoweth Run	167	March - May and September	0.010
				June	0.018
				July - August	0.024
Midland Trail Golf Club	1315	RM 37.55 of Floyds Fork	185	December - February	0.000
				March and November	0.250
				April - May and October	0.500
				June and Spetember	0.800
Rogers Group, Inc.- Bullitt Co Stone	1353	Bullitt County Stone quarry pit	109	January - December	1.100
Rogers Group, Inc.- Jefferson Co Stone	1355	Jefferson County Stone quarry	192	January - December	0.350
The Cardinal Club, LLC	1460	RM 5.2 of South Long Run (impoundment), a tributary of Long Run	278	October - April	0.000
				May - September	0.100

3.11 Septic Tanks

Information on septic systems in the Floyds Fork Watershed was obtained from County health departments. In most cases, the data was provided as either a rough estimate of the number of septic tanks in the County or as a rough percentage of the homes that have septic tanks. Rough estimates for the number of septic tanks were provided by County health departments in Henry, Oldham and Shelby County. Bullitt and Spencer County provided a rough percentage of homes that have septic tanks. For Jefferson County, septic tank coverage was provided by the Jefferson County MSD to obtain the number of septic tanks in the watershed. Therefore, for each County, septic tank data was input into the model to reflect the number of existing septic tanks in 2010.

In the model, the total number of septic tanks in each sub-watershed was determined from the County estimates using an area weighting approach. The number of septic tanks represented in each sub-watershed was determined by area weighting the individual sub-watershed area to the total area of the watershed assigned to the same County. Sub-watersheds were assigned to counties based on their outfall or pour point. The percentage of County area represented by each sub-watershed was used to determine the total number of septic tanks included in the model for each sub-watershed.

Septic tanks contribute to water quality whether they are functioning properly or failing. Both failing and non-failing septic tanks were modeled to incorporate the transport of pollutants for all septic conditions. Often, the scum layer on top of the wastewater hardens on the liquid surface which results in clogging the tank's inlet/outlet. This causes the septic tanks to fail (AGR-166). Therefore, a failing septic, as represented in the model, contributes pollutants to the land surface where they are available for runoff to the streams during rain events. Non-failing septics contribute to groundwater pollution. For all counties, except Oldham, it was assumed that at any given time, 20% of the overall number of septic tanks are failing, and 80% are working properly. For Oldham County, a reported annual failing percentage rate of 5% was used. The portion of septic tanks that were considered failing were modeled as a land use (Failing Septic) because it was assumed that no decay occurs and raw effluent is directly available to the land. It was determined that the average area of a septic field is 6,750 ft^2 (Inspectapedia 2009). Additional literature sources (AGR-167 and Engineering Toolbox 2011), provide a range of septic field areas from 5,760-7,500 ft^2.

The land use area that was used to represent Failing Septics was subtracted from the Low Intensity Urban Pervious land use for each sub-watershed. If Low Intensity Urban Pervious land use was not available, then Developed Open Space was used. For a few of the sub-watersheds there was no area under the designation of Low Intensity Urban Pervious or Developed Open Space. For these sub-watersheds, the land use for Failing Septics was assigned to the sub-watershed immediately downstream of it. Non-failing septic tanks were modeled as very small individual point sources within each sub-watershed. Section 5.9 further discusses how both failing and non-failing septic tanks were handled in the water quality model.

3.12 Sinkholes

Most of the Floyd's Fork watershed is geologically located in the Outer Bluegrass physiographic region which is characterized by deep valleys followed by little flat land and karst features like sinkholes and springs. The Knobs physiographic region contains the confluence of Floyds Fork with the Salt River, Blue Lick creek, Clear Run, and the western portion of Brooks run (KGS 2011). With the presence of Karst features, ground water becomes vulnerable to pollution due to rapid flow rates and the lack of a natural filtration system for the contaminants. In addition, available transportation pathways for pollutants between surface water and ground water can result in pollution of groundwater and contamination of wells and surface water.

As shown in Figure 3-11, the Floyds Fork watershed has three karst classifications: 'Karst Major', 'Karst Minor' and 'Non-Karst'. 'Karst Major' represents the areas of high potential for karst and it covers 18% of the Floyds Fork watershed. Karst Minor represents areas of lower potential for karst formations and it covers 76% of the region. The remaining area has little to no potential for karst development. The classification of the potential for karst development was based on the field experience of Geologists from the Kentucky Geological Survey (KGS) and the percentage of land underlain by limestone and other carbonate rocks. The most significant karst feature in the Floyds Fork watershed is sinkholes. A sinkhole is a depression in the surface of the ground that is formed when a fracture in the limestone becomes enlarged (Currens 2002). The sinkhole data used in the model was provided by two sources, SSURGO and KGS. The data was then merged into a single coverage for further processing. Duplicate sinkholes were eliminated to avoid redundancy. The combined SSURGO and KGS coverage identified an area of 0.493 sq. miles of sinkholes in the Floyds Fork watershed, or approximately 0.17% of the entire Floyds Fork watershed area.

Sinkholes were processed as a separate land use in the Floyds Fork watershed model so that unique parameters could be used to represent the karst features. Each of the sinkhole was intersected with the sub-watershed delineations. Then, the NLCD land use coverage and percent impervious coverage were processed to estimate the land use currently assigned to each sinkhole. In general, the sinkholes are currently classified by 8 land use categories: Open Water, Urban, Barren, Forest, Grassland, Pasture/Hay, Cultivated Crops and Wetland. For the model application, the area represented by each sinkhole was subtracted from the corresponding land use classification to make sure that the areas were not double counted.

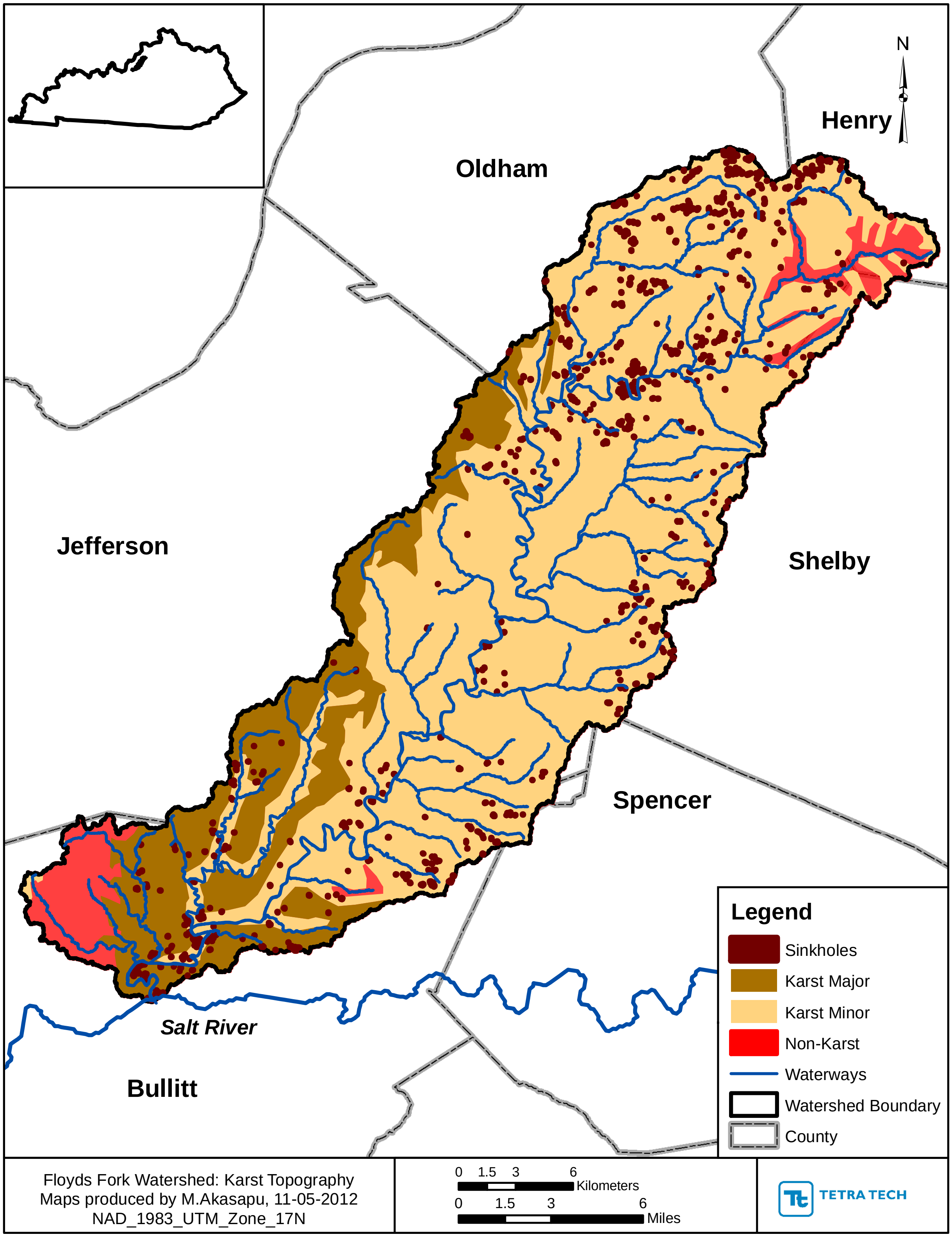


Figure 3-11 Sinkholes in the Floyds Fork Watershed

3.13 Springs

In addition to Sinkholes, another significant karst feature found in the Floyds Fork Watershed is the subsurface springs. Springs are points where the groundwater rises to the surface and becomes surface water. Springs can deliver large volumes of water, particularly when they are fed by a collection of sinkholes joined together underground (Currens 2002).

The USGS has identified 20 springs in the Floyds Fork watershed which are concentrated along the main stem of Floyds Fork (Figure 3-12). A list of the 20 springs with their respective discharges used in the model is tabulated in Table 3-12. During the calibration it was observed that the USGS flow station located on Pennsylvania run (03298300) was predicting low flows. Based on the hydrogeology, it was assumed that there was an unidentified spring, and therefore an additional spring was input into the model at a flow of 0.30 cfs. The water quality concentrations used for the springs were average groundwater concentrations taken from KGS's groundwater-quality database of the Kentucky groundwater data repository (Table 3-13). The flow and groundwater concentration for the springs were input directly into the LSPC model as time-series from 2000 to 2010.

During the calibration it was observed that for a couple of water quality stations, concentrations assigned to the springs were negatively influencing the calibration results. This mainly occurred at water quality stations on small tributaries. The default concentrations for springs SPR6, SPR7, SPR8, SPR9, SPR19, and SPR20 were changed to improve the calibration.

Table 3-12 Springs included in the Floyds Fork watershed model

Spring Number	USGS Name	County	Discharge, cfs
SPR1	E17CS001	Bullitt	0.10
SPR2	E17BS002	Jefferson	0.10
SPR3	E17BS004	Jefferson	0.10
SPR4	E17BS001	Jefferson	0.10
SPR5	E18AS002	Jefferson	0.10
SPR6	E18AS001	Jefferson	0.01
SPR7	E17BS003	Jefferson	1.00
SPR8	E17BS006	Jefferson	0.10
SPR9	E17BS005	Jefferson	0.10
SPR10	D18C009	Jefferson	0.05
SPR11	D18CS004	Jefferson	0.05
SPR12	D18CS006	Jefferson	0.05
SPR13	D18C005	Jefferson	0.05
SPR14	D18CS007	Jefferson	0.10
SPR15	D18CS008	Jefferson	0.10
SPR16	D18CS011	Shelby	0.05
SPR17	D18CS002	Oldham	0.05
SPR18	D18CS003	Oldham	0.05
SPR19	D18CS004	Oldham	0.10
SPR20	ANITA SPRGS. WATER CO. - 1185001	Oldham	0.10

Table 3-13 Averaged groundwater concentrations for Springs

Constituent	Average GW concentration, mg/L
TN	3.57
NH3	0.06
NOX	3.31
ORGN	0.20
TP	0.14
PO4	0.08
ORGP	0.06
DO	1.85
BOD5	0.55
WTEMP	15.09

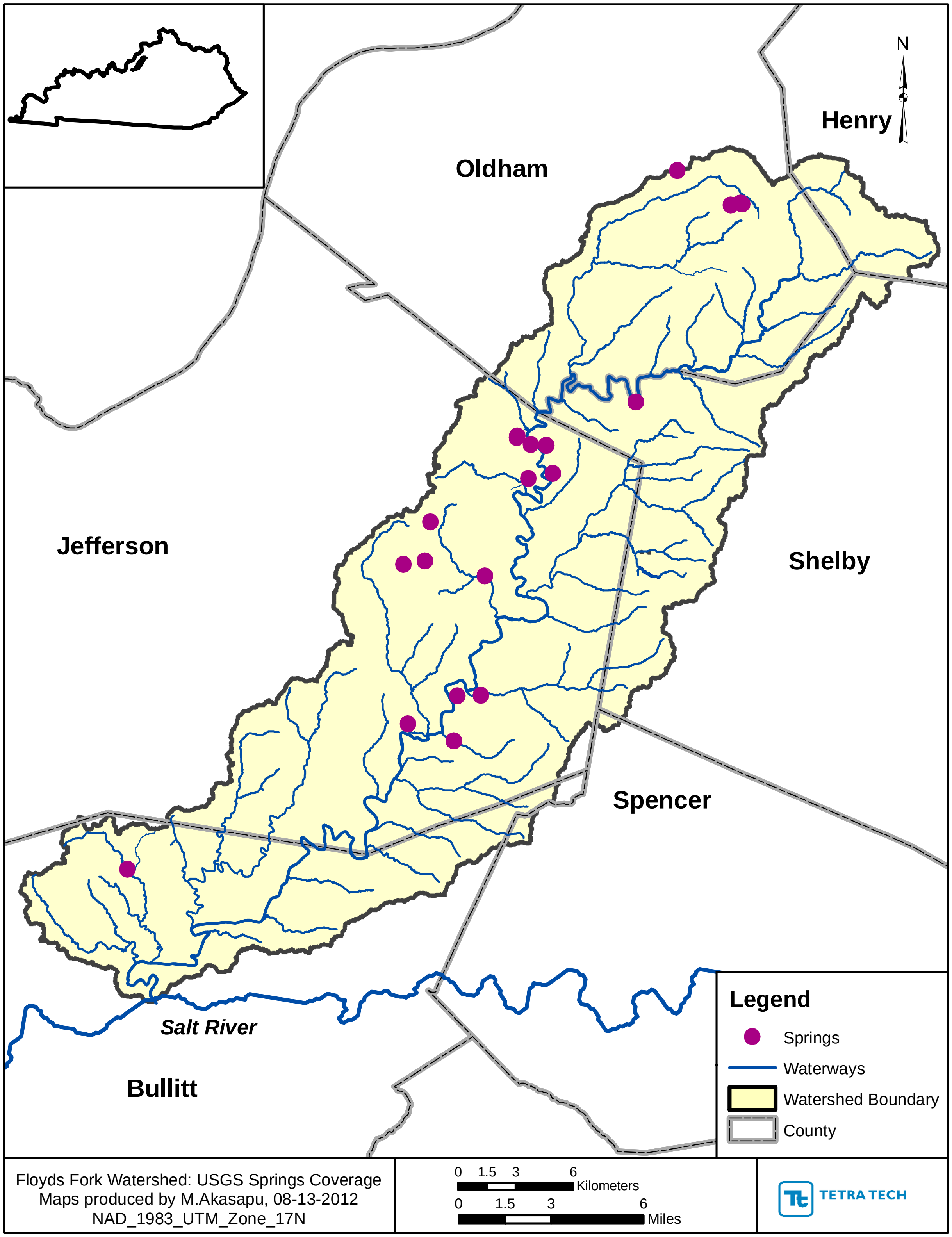


Figure 3-12 Springs in the Floyds Fork Watershed

3.14 Non-point source discharges

Pollution from diffuse sources, for instance, oil/grease from urban runoff or excess fertilizers/nutrients from livestock on agricultural lands, by definition, are non-point sources. It is difficult to estimate these sources as they are dispersed over a wide area and are variable in time. Nutrient loads from non-point sources, such as agricultural land use, can be estimated based on applied fertilizer rates, crop requirements and livestock manure. For the Floyds Fork watershed model, loads from fertilizers and livestock manure were estimated for the Cropland and Pastureland land uses and are presented in sections 3.14.1 and 3.14.2. Nutrient loads from Golf Courses and MS4 areas are presented in sections 3.14.3 and 3.14.4 respectively. For all other land uses, nutrient loads were determined through calibration of the model.

3.14.1 Nutrient Loads from Fertilizers

Total Nitrogen (TN) and Total Phosphorus (TP) loads from fertilizers were estimated as average loading rates on a yearly basis. The estimation of nutrient loads from fertilizers was based on the assumption that the farm fertilizer was applied only to the Cropland land use. The application rate of Nitrogen and Phosphate based fertilizer for the primary crops within the Floyds Fork watershed (Corn, Soft Red Winter Wheat, Soybeans and Burley Tobacco) were obtained from the United States Department of Agriculture's National Agricultural Statistics Service (USDA-NASS) (Table 3-14). Regional information for application rates were available for Corn and Soybeans, but were not available for Wheat or Tobacco. Therefore, for Wheat, application rates from multi-state data were utilized. For Tobacco, the application rate recommended by the University of Kentucky's faculty was used. The application rates were then supplied to all six counties in the watershed (Table 3-15). The mass of fertilizer applied (TN and TP) to the crops per year was computed as shown in the equation below. The 10–year planted and harvested acreage for each of the four primary crops in the County was obtained from USDA-NASS.

$$\text{Mass of Fertilizer applied}\left(\frac{\text{lbs}}{\text{year}}\right) = \text{Application rate} \times \text{Planted Crop}_c\ \text{acreage}$$

where c represents the individual crop.

Table 3-14 Fertilizer application rates in the Floyds Fork Watershed

County	Year	Average Fertilizer Application rate, lbs/acre/year	
		Nitrogen	Phophate
Corn	2010	164	99
Soybean	2006	38	64
Tobacco	-	200*	93**
Wheat**	2009	70	31

* Application rate based on information from UK's faculty.

** No regional information was available and therefore, multi-state results were considered.

Table 3-15 Fertilizer application rates for each crop in the Floyds Fork Watershed

County	TN, lbs/acre/year				TP, lbs/acre/year			
	Corn	Soybeans	Tobacco	Wheat	Corn	Soybeans	Tobacco	Wheat
Bullitt	164	38	200	70	99	64	93	31
Henry	164	38	200	70	99	64	93	31
Jefferson	164	38	200	70	99	64	93	31
Oldham	164	38	200	70	99	64	93	31
Shelby	164	38	200	70	99	64	93	31
Spencer	164	38	200	70	99	64	93	31

Crops remove nutrients from the supply of fertilizer in order to grow. By definition, crop nutrient removal rates are the quantity of nutrients removed from a harvested portion of the crop (AGR-1). The crop removal rates used for Floyds Fork watershed are a result of soil fertility research and soil test data in Kentucky. These rates are published by the University of Kentucky's Cooperative extension service (Table 3-16). The literature crop nutrient removal rates at standard harvest moisture were used to estimate the uptake by crops (lbs/year) for each County. To estimate the mass of nutrients taken up by the crop per year, the 10-year yield data for the representative crops was obtained from the USDA-NASS.

Table 3-16 Literature crop removal rates used in the Floyds Fork Watershed

Crop	Yield Unit	Nutrients removed, lbs/Yield unit	
		N	P_2O_5
Corn for grain	bu	0.7	0.4
Corn for silage	ton	7.5	3.5
Wheat for grain	bu	1.2	0.5
Wheat for silage	ton	44	4
Soybeans	bu	3	0.7
Tobacco	100 lbs	7	1.1

The mass of nutrients taken up by the crop were estimated using the following equations. As shown in the equation for P, the removal rate was divided by 2.3 to convert P_2O_5 to P.

$$\begin{matrix}\text{Mass of N}\\ \text{taken up by the crop}\end{matrix}\left(\frac{\text{lbs}}{\text{year}}\right) = \text{Yield of the crop}_c \times \text{Literature crop}_c\text{ removal rate for N}$$

$$\begin{matrix}\text{Mass of P}\\ \text{taken up by the crop}\end{matrix}\left(\frac{\text{lbs}}{\text{year}}\right) = \frac{\text{Yield of the crop}_c \times \text{Literature crop}_c\text{ removal rate for }P_2O_5}{2.3}$$

where c represents the individual crop including grain and silage.

After the nutrients were removed by the crops from the harvested portion of the crop, the excess nutrients remaining in the watershed were computed as shown in the equation below. The mass of nutrients removed by grain and silage for corn and wheat was summed and then subtracted from the fertilizer applied to these crops.

$$\text{Excess nutrients in the watershed}\left(\frac{\text{lbs}}{\text{year}}\right) = \text{Mass of fertilizers applied} - \text{Mass of nutrients removed by the crop}_c$$

where c represents the individual crop.

A percentage of the excess nutrients present in the watershed get converted into different forms which allow losses to the atmosphere. A default percentage for the additional losses from the excess nutrients was applied to calculate the nutrients available for runoff as presented in the equation below. It was assumed that 60% of N and 95% of P gets lost from the system. The calculated mass of nutrients available for runoff was further converted to a rate based on a year. However, if the mass of N removed by soybean was greater than the mass of the applied fertilizer, the loading rate was set to zero.

$$\text{Additional losses}\left(\frac{\text{lbs}}{\text{year}}\right) = \text{Excess nutrients} \times \%\text{ of additional losses for the excess nutrients}$$

$$\text{Nutrients available for runoff}\left(\frac{\frac{\text{lbs}}{\text{acre}}}{\text{day}}\right) = \frac{\text{Excess nutrients} - \text{Additonal losses}}{\left(\sum \text{Harvested acres}_c\right) \text{ x } (365)}$$

where c represents the individual crop including grain and silage.

Nutrients available for runoff were extracted from the entire dataset by County and by crop. Then, the extracted data was used to develop a summarized statistic table indicating minimum, maximum, mean, 25th, 50th , and 75th percentile loading rate for TN and TP in each of the six counties, and for each of the four primary crops. The 50th percentile loading rate was used for the Floyds Fork watershed model based on suggestions from the University of Kentucky's faculty. The 50th percentile loading rate for each crop and its respective County was then multiplied with the percentage of the acreage of the crop in the entire harvested acreage for the County. The loading rates from all of the crops were then summed for the individual counties. Finally, the loading rate was area weighted based on the Cropland acreage in the watershed. The sum of area weighted loading rates from all the six counties was used as the final fertilizer loading rate for Cropland (see equations below). Table 3-17 presents the calculated loading rates for Cropland used in the Floyds Fork Watershed.

$$\text{Nutrient loading rate}\left(\frac{\frac{\text{lbs}}{\text{acre}}}{\text{day}}\right) = \begin{matrix}50^{\text{th}}\text{ percentile}\\ \text{loading rate}\end{matrix} \times \%\left(\frac{\text{10-yr county}_C\text{ average harvested crop}_c\text{ acreage}}{\sum \text{10-yr county}_C\text{ average harvested crop}_c\text{ acreage}}\right)$$

$$\text{Area weighted Nutrient loading rate}\left(\frac{\frac{\text{lbs}}{\text{acre}}}{\text{day}}\right) = \begin{matrix}\text{Nutrient}\\ \text{loading rate}\end{matrix} \times \left(\frac{\text{Cropland acreage per county in the watershed}}{\sum \text{Cropland acreage per county in the watershed}}\right)$$

where C represents the individual county
c represents the individual crop including grain and silage.

Table 3-17 Calculated loading rates from Fertilizers for Cropland used in the Floyds Fork watershed

Area weighted 50th percentile loading rates for Cropland, lbs/acre/day												
Month	January	February	March	April	May	June	July	August	September	October	November	December
TN	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059
TP	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011

3.14.2 Nutrient Loads from Livestock Manure

Another economical and significant source of nutrients applied to Cropland and Pastureland is livestock manure. The total number of acres in Cropland was obtained from USDA-NASS as mentioned in section 3.14.1 and the Pastureland acreage was obtained from 2007 Census Report (Table 3-18). For the Floyds Fork watershed it was assumed that the nutrients from fertilizer provided an adequate supply of nutrients for the crops in Cropland, therefore, livestock manure was applied only on the Pastureland land use. For the Floyds Fork watershed model, animals considered for Pastureland were: Beef cattle, Dairy cattle, and Horses. Despite zero contribution from manure loads from Hogs and Layers in the current watershed model, the loads were included in the Tables below. The number of animals present in the County was obtained from the 2007 Census Report (Table 3-19). The number of animals present in the watershed was area weighted between the County and the watershed based on the acreage presented in Table 3-18.

Table 3-18 Acreage of Cropland and Pastureland treated with manure in the Floyds Fork watershed

County	All numbers are in acres			
	Cropland* in the County	Pastureland** in the County	Cropland in the watershed	Pastureland in the watershed
Bullitt	8157	24564	1675	6417
Henry	12714	90629	208	3966
Jefferson	2788	19198	2846	12619
Oldham	8855	40204	2380	12969
Shelby	42498	125103	1255	12651
Spencer	10830	39808	3	381
Total	85843	339506	8367	49001

* USDS-NASS

** Census of Agriculture, 2007

Table 3-19 Count of Agricultural animals used in the Floyds Fork watershed

County	County					Watershed				
	No. of Dairy cattle	No. of Beef cattle	No. of Hogs	No. of Layers	No. of Horses	No. of Dairy cattle	No. of Beef cattle	No. of Hogs	No. of Layers	No. of Horses
Bullitt	237	3693	445	1457	1138	59	913	110	360	281
Henry	1292	14638	58	1174	1826	52	591	2	47	74
Jefferson	0*	1768	73	1131	1905	0	1244	51	796	1340
Oldham	369	4244	18	669	2838	115	1328	6	209	888
Shelby	2034	16191	51	4792	5079	169	1343	4	398	421
Spencer	401	6985	248	1860	882	3	53	2	14	7

* No data

The nutrient content of manure varies by factors such as the type of animal, manure's moisture content and type and amount of bedding used (AGR-146). The manure production and characteristics published by the Natural Resources Conservation Service (NRCS) and American Society of Agricultural Engineers (ASAE) was used to characterize the livestock manure (Table 3-20). The fresh manure characteristics for TN and TP were for 1000 lbs of live animal per day (ASAE, 2003). The estimated nutrients produced by these animals were based on a typical live animal for which these manure values were reported.

Table 3-20 Typical manure characteristics used in the Floyds Fork watershed

Animal	Tons of manure per Animal Unit**	No. of animals per Animal Unit	lbs of nutrients per ton of manure***		lbs of nutrients/ animal/ day	
			N	P	N	P
Dairy cow	15.24	0.74	11.00	4.00	0.603	0.221
Beef cow	11.50	1.00	11.00	3.00	0.345	0.096
Hogs and Pigs	14.69	9.09	9.00	4.00	0.040	0.017
Poultry (Layer)	11.45	250.00	30.00	17.00	0.004	0.002
Horses*	-	-	-	-	0.300	0.071

* Manure rates have been derived from ASAE, 2003. The numbers are for manure rates/1000lbs/day.
** nrcs: Appendix ii
*** AGR-146

Based on conversations with the University of Kentucky's faculty, a percentage was applied to calculate the load of manure available for runoff. Percentages of 30 and 5 were used to calculate the load available for runoff for TN and TP, respectively (Table 3-21). The manure loads from all of the agricultural animals represented in the watershed model were computed as shown in the equation below. The total manure loads available for runoff, from all the agricultural animals in Floyds Fork is presented in Table 3-22.

$$\begin{matrix}\text{Manure load}\\ \text{available for runoff}\end{matrix}\left(\frac{\text{lbs}}{\text{day}}\right)=\begin{matrix}\text{No. of animals}_a\\ \text{present in the watershed}\end{matrix}\times\begin{matrix}\text{Manure rate}\\ \text{of the animal}_a\end{matrix}\times\left(\begin{matrix}\text{\% availability of manure}\\ \text{for runoff}\end{matrix}\right)$$

where a represents the individual agricultural animal.

Table 3-21 Percent of nutrients in manure available for runoff in the Floyds Fork watershed

Nutrient	% available
Nitrogen	30
Phosphate	5

Table 3-22 Total Manure load available for runoff used in the Floyds Fork watershed

County	lbs of N/day					lbs of P/day				
	Dairy Cattle	Beef Cattle	Hogs	Layers	Horses	Dairy Cattle	Beef Cattle	Hogs	Layers	Horses
Bullitt	10.605	94.516	1.315	0.407	25.326	0.647	4.378	0.095	0.039	4.221
Henry	9.443	61.194	0.028	0.054	6.638	0.576	2.835	0.002	0.005	1.106
Jefferson	0.000	128.715	0.614	0.898	120.599	0.000	5.963	0.044	0.087	20.100
Oldham	20.890	137.423	0.067	0.236	79.910	1.274	6.366	0.005	0.023	13.318
Shelby	30.537	139.037	0.051	0.449	37.926	1.863	6.441	0.004	0.043	6.321
Spencer	0.549	5.470	0.022	0.016	0.601	0.033	0.253	0.002	0.002	0.100

Table 3-23 presents the percent of the agricultural animals in Pastureland. It was suggested by the University of Kentucky's faculty that 40% of dairy cattle and 100% of beef cattle and horses are available in Pastureland. Based on the percent availability of animals and the available data on manure loads, the loading rate per county per agricultural animal was calculated over the entire Pastureland acreage present in the watershed. The loading rates from all the agricultural animals present in the watersheds were summed to get the total loading rate for a County. Finally, the sum of the area weighted loading rates from all the six counties was applied as the final loading rate from manure for Pastureland (Table 3-24). The manure loading rate for TN for Pastureland was added with the atmospheric deposition rate of 0.015 lbs/acre/day to get the final loading rate for TN. Table 3-25 presents the loading rates calculated for Pastureland in the Floyds Fork Watershed.

Table 3-23 Percent of Agricultural Animals in Pastureland used in the Floyds Fork watershed

Animal	%
Dairy Cattle	40
Beef Cattle	100
Hogs	0
Layers	0
Horses	100

Table 3-24 Manure loading rate from Pastureland used in the Floyds Fork watershed

Pastureland														
County	N, lbs/acre/day					Total TN loading rate, lbs/acre/day	Area weighted TN loading rates, lbs/acre/day	P, lbs/acre/day					Total TP loading rate, lbs/acre/day	Area weighted TP loading rates, lbs/acre/day
	Dairy Cattle	Beef Cattle	Hogs	Layers	Horses			Dairy Cattle	Beef Cattle	Hogs	Layers	Horses		
Bullitt	0.001	0.015	0.000	0.000	0.004	0.019	0.002	0.000	0.001	0.000	0.000	0.001	0.001	0.000
Henry	0.001	0.015	0.000	0.000	0.002	0.018	0.001	0.000	0.001	0.000	0.000	0.000	0.001	0.000
Jefferson	0.000	0.010	0.000	0.000	0.010	0.020	0.004	0.000	0.000	0.000	0.000	0.002	0.002	0.000
Oldham	0.001	0.011	0.000	0.000	0.006	0.017	0.004	0.000	0.000	0.000	0.000	0.001	0.002	0.000
Shelby	0.001	0.011	0.000	0.000	0.003	0.015	0.003	0.000	0.001	0.000	0.000	0.000	0.001	0.000
Spencer	0.001	0.014	0.000	0.000	0.002	0.017	0.000	0.000	0.001	0.000	0.000	0.000	0.001	0.000
Total area weighted TN loading rate, lbs/acre/day							0.015	*Total area weighted TP loading rate, lbs/acre/day*						0.001

Table 3-25 Calculated loading rates for Pastureland for the Floyds Fork watershed

Calculated Loading rates for Pastureland, lbs/acre/day												
Month	January	February	March	April	May	June	July	August	September	October	November	December
TN	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030	0.030
TP	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003

During the model calibration, it was observed that when using the calculated Pastureland loading rates shown in Table 3-25, simulated results at in-stream water quality stations where the dominate load was from Pastureland and Forest land uses, were much lower than the measured data. Most of the samples for measured data were taken during the growing season (April through October). During this period, several spikes were observed within a few days of a rain event, suggesting loads coming from the land use runoff. This was especially true for TN. Based on these trends observed during the calibration process, the loading rates from Pastureland for TN were increased by 40%. The TP rates were unchanged. Table 3-26 presents the loading rates for Pastureland used in the Floyds Fork Watershed.

Table 3-26 Loading rates for Pastureland used in the Floyds Fork watershed

Calculated Loading rates for Pastureland, lbs/acre/day												
Month	January	February	March	April	May	June	July	August	September	October	November	December
TN	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042
TP	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003

3.14.3 Nutrient Loads from Golf Courses

Fourteen golf courses were identified in the Floyds Fork watershed. Estimates of fertilizer application for these golf courses were based on the information obtained from the Superintendent of Golf Courses in the Louisville Metro Parks and Recreation Department who manages nine Metro Golf Courses in the Louisville area, two of which lie in the Floyds Fork Watershed. Based on fertilizer application information provided for the two golf courses, Long Run and Charlie Vettiner, the average application rate applied to the golf courses was used in the calculation of the loading rates (Table 3-27). The application rate for golf courses for the respective golf course feature (Greens, Fairways, Rough, and Tee Tops) was provided on a square foot basis which was converted to per acre to facilitate the calculation of the loading rates.

Golf courses were not considered as a separate land use category, and were therefore incorporated with the Grassland land use for the Floyds Fork model. Based on the aerial maps and geospatial processing, it was roughly estimated that the golf courses comprised of 1268 acres in the Floyds Fork watershed. It was assumed that the average greens and tee tops per golf course was 3.5 acres and 1.75 acres, respectively. 30 percent of the remaining area was assumed to be Fairways and the rest, Rough areas. The application rate for golf courses per golf feature is presented in Table 3-27. The initial loading rate for the rest of the Grassland acreage was assumed based on the literature loading rates and was used as a calibration parameter. The application rates for golf courses and the loading rates for the Grassland was area weighted to get an initial loading rate for the entire Grassland land use (Table 3-28). The assumed loading rate for the Grassland (except Golf course) was then adjusted during the calibration process.

Table 3-27 Typical Fertilizer application to Golf courses used in the Floyds Fork watershed

	Month	Jan	Feb	March	April	May	June	July	August	Sep	Oct	Nov	Dec
TN Fertilizer Application rate, lbs/acre/day	Greens				0.290	0.281	0.290	0.281	0.281	0.290			
	Fairways				1.452								
	Rough areas		0.778										
	Tea Tops			1.405					1.405				
Total Load from golf courses, lbs/day			650.630	34.426	534.733	13.771	14.230	13.771	48.197				
	Month	**Jan**	**Feb**	**March**	**April**	**May**	**June**	**July**	**August**	**Sep**	**Oct**	**Nov**	**Dec**
TP Fertilizer Application rate, lbs/acre/day	Greens				0.473								
	Fairways												
	Rough areas		0.156										
	Tea Tops												
Total Load from golf courses, lbs/day			130.126		23.200								

Table 3-28 Calculated loading rates for Grassland used in the Floyds Fork watershed

Calculated Loading rates for TN for Grassland, lbs/acre/day												
Month	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**
Soil Group: B	0.036	0.137	0.082	0.175	0.151	0.247	0.247	0.252	0.245	0.161	0.044	0.032
Soil Group: C	0.099	0.200	0.105	0.203	0.248	0.321	0.321	0.326	0.318	0.209	0.162	0.146
Soil Group: D	0.099	0.200	0.105	0.203	0.248	0.321	0.321	0.326	0.318	0.209	0.162	0.146
Calculated Loading rates for TP for Grassland, lbs/acre/day												
Month	**January**	**February**	**March**	**April**	**May**	**June**	**July**	**August**	**September**	**October**	**November**	**December**
Soil Group: B	0.004	0.024	0.004	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.004
Soil Group: C	0.047	0.087	0.067	0.091	0.204	0.204	0.204	0.204	0.204	0.073	0.073	0.047
Soil Group: D	0.047	0.087	0.067	0.091	0.204	0.204	0.204	0.204	0.204	0.073	0.073	0.047

3.14.4 Nutrient Loads from Urban areas

Nutrient loading rates for each urban land use category were determined using sample data from the Metropolitan Sewer District's (MSD) Laboratory Information Management System (LIMS). The MS4 land use categories included Public and Semi-Public, Industrial, General Commercial and Office, Multi-Family Residential, Single-Family Residential, Parks and Cemeteries, and Vacant and Undeveloped. The sample set was developed with the intent to collect nutrient concentrations from the individual MS4 land use categories. Sites representing each MS4 land use category were identified and samples were collected over multiple dates and varied flow conditions. The compiled sample data included:

- Sample Number,
- Address / Latitude and Longitude of the Sample Location,
- Collection Date,
- Analyte Description,
- Concentration Results in mg/L, and
- MS4 Land use Type.

For this modeling effort, the goal was to utilize the data by converting the sample concentrations to loading rates for each MS4 land use category, followed by a statistical analysis to identify corresponding loading rates for the Urban-Pervious land use categories represented in the watershed model.

The first step was to compile the data into a Geographical Information Systems (GIS) project in order to perform a geospatial analysis. Each site was located using the reported latitude and longitudes. Drainage areas for each sample site were then delineated and their proximity to the USGS flow gages was recorded. Using the USGS gage closest to each sample site, flow records were evaluated and the daily average flow for the sample date was determined. The flow to each sample site was then area weighted using the following equation:

$$\begin{matrix}\text{Sample site}\\ \text{flow}\end{matrix}\ (\text{cfs}) = \frac{\text{USGS Flow}}{\text{USGS drainage area}} \times \text{Sample site drainage area}$$

After the flows were determined for each sample site, loading rates were calculated in lbs/acre/day using the following equation:

$$\text{Loading rate}\ \left(\frac{\frac{\text{lbs}}{\text{acre}}}{\text{day}}\right) = \frac{8.34 \times \text{sample concentration} \times (\text{sample site flow} \times 0.646272)}{\text{Sample site drainage area}}$$

Units in the equation are: concentration in mg/L, flow in cfs, and drainage area in acres.

Box and whisker plots for TN and TP loading rates have been presented in figures 3-13 and 3-14. There was no TN data available for Vacant and Undeveloped land use category.

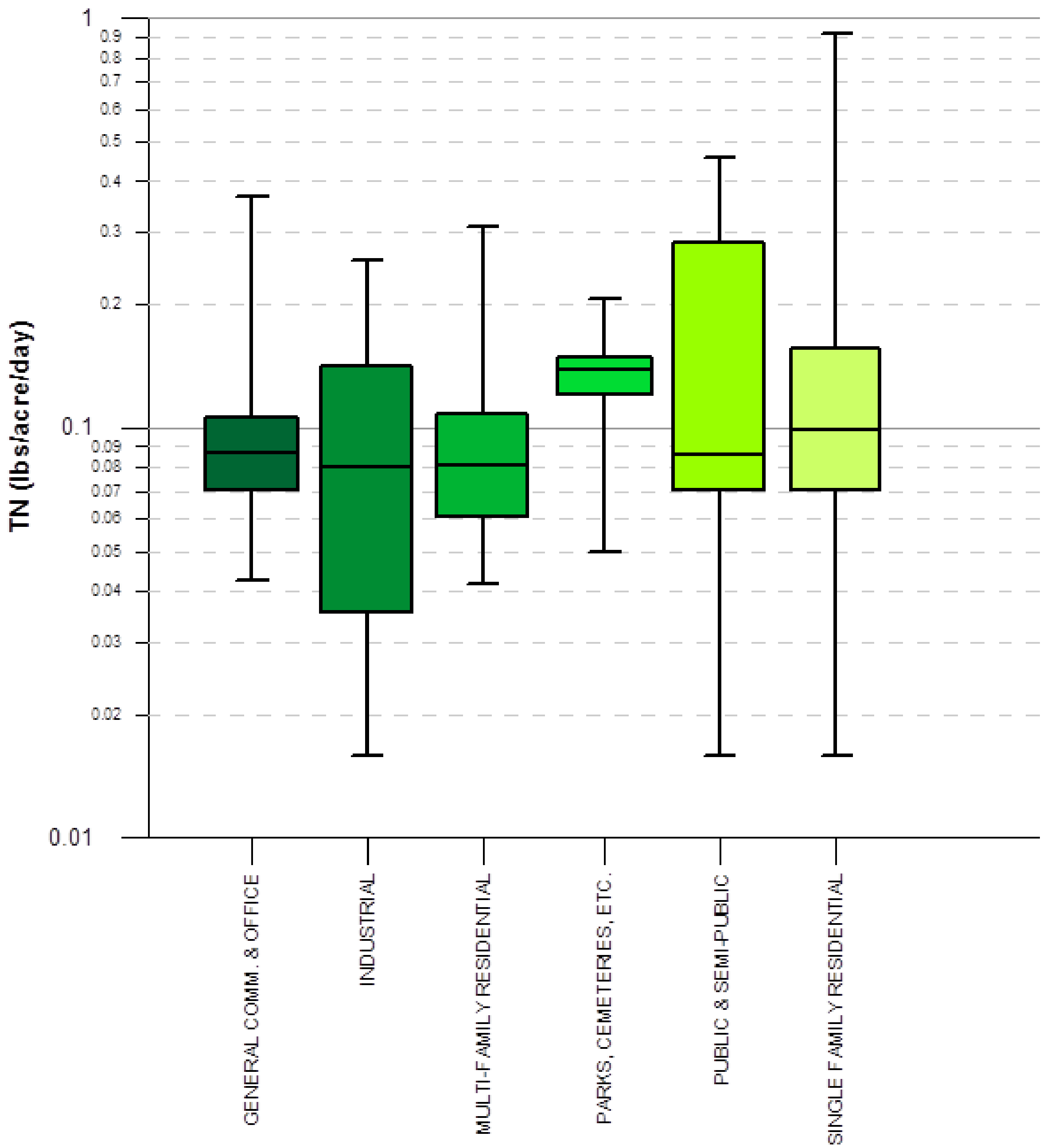


Figure 3-13 Box and Whisker Plot for TN Loading Rate (lbs/acre/day) for the MS4 Land Use categories

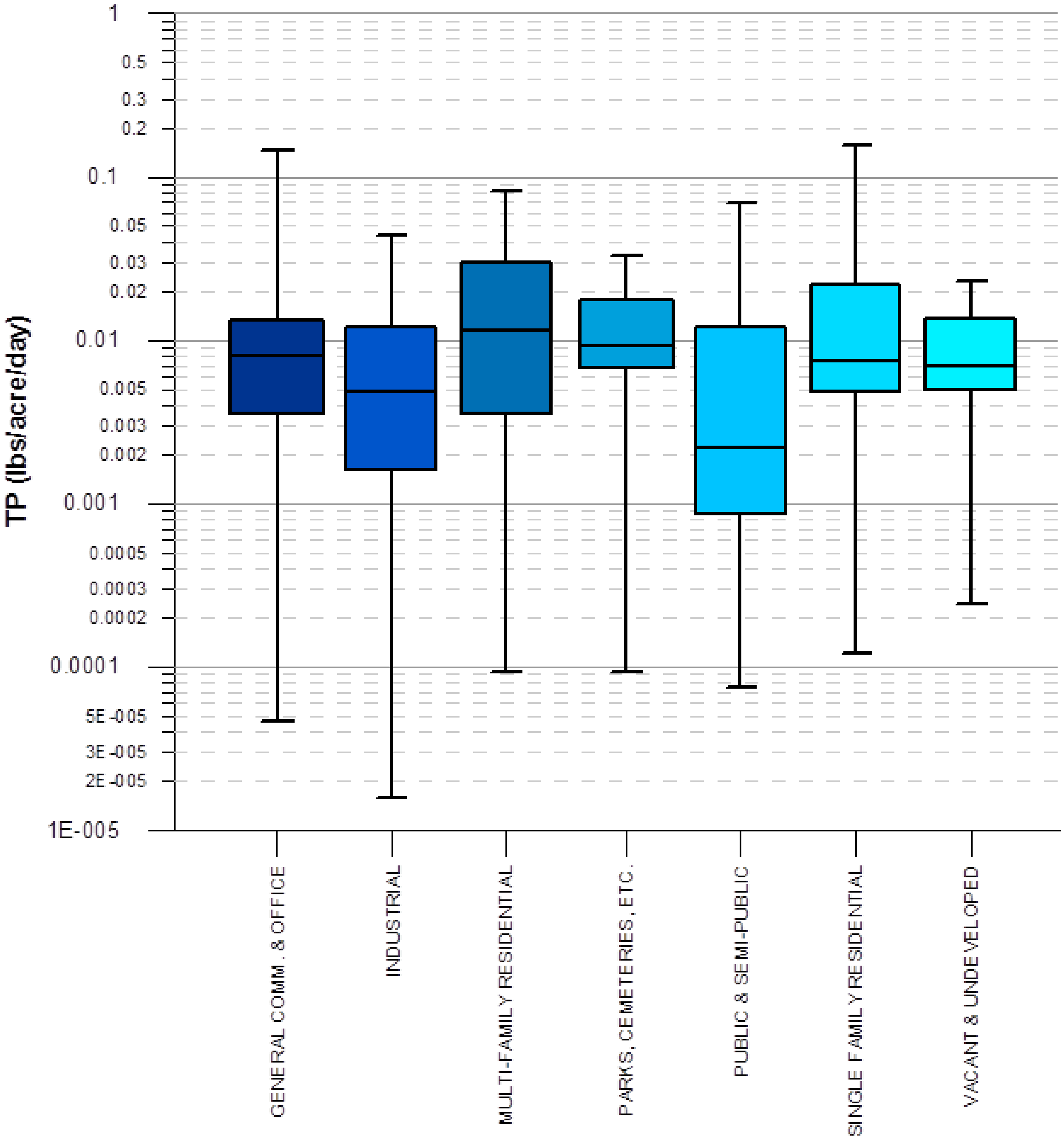


Figure 3-14 Box and Whisker Plot for TP Loading Rate (lbs/acre/day) for the MS4 Land Use categories

For the statistical analysis, the loading rates were compiled based on each unique MS4 land use category. For each MS4 land use category, the minimum, 25th percentile, 50th percentile, average, 75th percentile, 95th percentile, and maximum loading rates were calculated. Next, the MS4 land uses were assigned to the corresponding Urban-Pervious land use categories represented in the watershed model (Table 3-29). The MS4 loading rates were then averaged and assigned to the corresponding watershed land use category. TN and TP loading rates calculated for the Urban-Pervious land use categories used in the watershed model are shown in Tables 3-30 and 3-31 respectively.

Table 3-29 MS4 land use categories corresponding to Urban-Pervious land use categories used in the Floyds Fork watershed

MS4 Land use Category	Corresponding LSPC Watershed Model Land use Category
Public and Semi-Public	High Intensity Developed, Pervious
Industrial	
Multi-Family Residential	
General Commercial and Office	Medium Intensity Developed, Pervious
Parks, Cemeteries	Low Intensity Developed,Pervious
Single Family Residential	
Vacant and Undeveloped	

Table 3-30 Statistics for TN loading rates for Urban-Pervious Land uses

MS4 Land Use category	Minimum	25th Percentile	50th Percentile	Average	75th Percentile	95th Percentile	Maximum	Watershed model Land Use category	Minimum	25th Percentile	50th Percentile	Average	75th Percentile	95th Percentile	Maximum
Public and Semi-Public	0.016	0.070	0.086	0.165	0.279	0.417	0.458	High Intensity Developed, Pervious	0.024	0.058	0.083	0.124	0.168	0.309	0.342
Industrial	0.016	0.040	0.081	0.092	0.121	0.201	0.257								
Multi-Family Residential	0.041	0.063	0.081	0.114	0.106	0.310	0.312								
General Commercial and Office	0.043	0.075	0.087	0.101	0.106	0.179	0.367	Medium Intensity Developed, Pervious	0.043	0.075	0.087	0.101	0.106	0.179	0.367
Parks, Cemeteries	0.050	0.122	0.138	0.050	0.149	0.187	0.206	Low Intensity Developed, Pervious	0.022	0.064	0.079	0.069	0.101	0.227	0.374
Single Family Residential	0.016	0.070	0.099	0.158	0.155	0.495	0.917								
Vacant and Undeveloped	0.000	0.000	0.000	0.000	0.000	0.000	0.000								

Table 3-31 Statistics for TP loading rates for Urban-Pervious Land uses

MS4 Land Use category	Minimum	25th Percentile	50th Percentile	Average	75th Percentile	95th Percentile	Maximum	Watershed model Land Use category	Minimum	25th Percentile	50th Percentile	Average	75th Percentile	95th Percentile	Maximum
Public and Semi-Public	0.000	0.001	0.002	0.009	0.011	0.032	0.069	High Intensity Developed, Pervious	0.000	0.002	0.006	0.013	0.018	0.040	0.065
Industrial	0.000	0.002	0.005	0.008	0.012	0.019	0.044								
Multi-Family Residential	0.000	0.004	0.011	0.021	0.029	0.070	0.083								
General Commercial and Office	0.000	0.004	0.008	0.012	0.013	0.033	0.144	Medium Intensity Developed, Pervious	0.000	0.004	0.008	0.012	0.013	0.033	0.144
Parks, Cemeteries	0.000	0.007	0.009	0.012	0.016	0.029	0.033	Low Intensity Developed, Pervious	0.000	0.006	0.008	0.012	0.016	0.028	0.070
Single Family Residential	0.000	0.005	0.007	0.015	0.022	0.039	0.156								
Vacant and Undeveloped	0.000	0.005	0.007	0.008	0.009	0.018	0.023								

The statistical calculations shown in Tables 3-30 and 3-31 for the Urban-Pervious land use categories were utilized to develop the monthly loading rates for TN and TP in the LSPC model. During calibration, it was observed that the 95th percentile for TN and 50th percentile for TP best captured the trends and magnitude at the stations dominated by these land uses. Therefore, these values were applied using a sine curve to simulate monthly variability. The adjusted loading rates for the Urban-Pervious land uses are shown in Table 3-32.

Table 3-32 Calculated loading rates for Urban land uses used in the Floyds Fork watershed

Calculated Loading rates for TN for Urban Land uses, lbs/acre/day												
Month	January	February	March	April	May	June	July	August	September	October	November	December
Low Intensity Developed, Pervious	0.121	0.222	0.232	0.242	0.252	0.363	0.262	0.252	0.242	0.232	0.222	0.121
Medium Intensity Developed, Pervious	0.089	0.159	0.169	0.179	0.189	0.268	0.199	0.189	0.179	0.169	0.159	0.089
High Intensity Developed, Pervious	0.155	0.289	0.299	0.309	0.319	0.464	0.329	0.319	0.309	0.299	0.289	0.155
Calculated Loading rates for TP for Urban Land uses, lbs/acre/day												
Month	January	February	March	April	May	June	July	August	September	October	November	December
Low Intensity Developed, Pervious	0.004	0.006	0.007	0.008	0.009	0.012	0.010	0.009	0.008	0.007	0.006	0.004
Medium Intensity Developed, Pervious	0.004	0.006	0.007	0.008	0.009	0.012	0.010	0.009	0.008	0.007	0.006	0.004
High Intensity Developed, Pervious	0.003	0.004	0.005	0.006	0.007	0.009	0.008	0.007	0.006	0.005	0.004	0.003

3.14.5 Final Loading rates for all land use categories used in the Calibrated Watershed Model

Nutrient loading rates were calculated for the Cropland, Pastureland, Grassland, and Urban-Pervious land use categories. The initial loading rates for the remaining land use categories were assumed based on literature loading rates. These loading rates were then adjusted during the calibration process. The final loading rates for TN and TP for all the land use categories input into the watershed model are tabulated in Tables 3-33 and 3-34 respectively.

Table 3-33 Applied TN loading rates for all land use categories used in the Floyds Fork watershed model

TN, lbs/acre/day													Average Loading Rate, lbs/acre/day	Annual Loading Rate, lbs/acre/year
Soil Group: B														
Landuse Category	January	February	March	April	May	June	July	August	September	October	November	December		
Low Intensity Developed, Pervious	0.121	0.222	0.232	0.242	0.252	0.363	0.262	0.252	0.242	0.232	0.222	0.121	0.230	83.997
Medium Intensity Developed, Pervious	0.089	0.159	0.169	0.179	0.189	0.268	0.199	0.189	0.179	0.169	0.159	0.089	0.169	61.762
High Intensity Developed, Pervious	0.155	0.289	0.299	0.309	0.319	0.464	0.329	0.319	0.309	0.299	0.289	0.155	0.295	107.406
Low Intensity Developed, Impervious	0.015	0.018	0.020	0.020	0.028	0.043	0.048	0.050	0.050	0.038	0.023	0.015	0.030	11.128
Medium Intensity Developed, Impervious	0.015	0.018	0.020	0.020	0.028	0.043	0.048	0.050	0.050	0.038	0.023	0.015	0.030	11.128
High Intensity Developed, Impervious	0.015	0.018	0.020	0.020	0.028	0.043	0.048	0.050	0.050	0.038	0.023	0.015	0.030	11.128
All Other Developed, Impervious	0.015	0.018	0.020	0.020	0.028	0.043	0.048	0.050	0.050	0.038	0.023	0.015	0.030	11.128
Barren	0.025	0.030	0.035	0.035	0.050	0.080	0.090	0.095	0.095	0.070	0.040	0.025	0.056	20.430
Forest	0.015	0.017	0.018	0.025	0.038	0.050	0.059	0.063	0.063	0.037	0.019	0.010	0.034	12.604
Shrub	0.015	0.015	0.020	0.020	0.025	0.045	0.055	0.060	0.060	0.050	0.025	0.010	0.033	12.205
Grassland	0.036	0.137	0.082	0.175	0.151	0.247	0.247	0.252	0.245	0.161	0.044	0.032	0.151	54.974
Pastureland	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	15.457
Cropland	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	21.581
Soil Group: C and D														
Low Intensity Developed, Pervious	0.121	0.222	0.232	0.242	0.252	0.363	0.262	0.252	0.242	0.232	0.222	0.121	0.230	83.997
Medium Intensity Developed, Pervious	0.089	0.159	0.169	0.179	0.189	0.268	0.199	0.189	0.179	0.169	0.159	0.089	0.169	61.762
High Intensity Developed, Pervious	0.155	0.289	0.299	0.309	0.319	0.464	0.329	0.319	0.309	0.299	0.289	0.155	0.295	107.406
Low Intensity Developed, Impervious	0.015	0.018	0.020	0.020	0.028	0.043	0.048	0.050	0.050	0.038	0.023	0.015	0.030	11.128
Medium Intensity Developed, Impervious	0.015	0.018	0.020	0.020	0.028	0.043	0.048	0.050	0.050	0.038	0.023	0.015	0.030	11.128
High Intensity Developed, Impervious	0.015	0.018	0.020	0.020	0.028	0.043	0.048	0.050	0.050	0.038	0.023	0.015	0.030	11.128
All Other Developed, Impervious	0.015	0.018	0.020	0.020	0.028	0.043	0.048	0.050	0.050	0.038	0.023	0.015	0.030	11.128
Barren	0.025	0.030	0.035	0.035	0.050	0.080	0.090	0.095	0.095	0.070	0.040	0.025	0.056	20.430
Forest	0.023	0.023	0.030	0.030	0.038	0.068	0.083	0.090	0.090	0.075	0.038	0.015	0.050	18.308
Shrub	0.020	0.025	0.030	0.030	0.045	0.060	0.070	0.075	0.075	0.065	0.035	0.020	0.046	16.775
Grassland	0.099	0.200	0.105	0.203	0.248	0.321	0.321	0.326	0.318	0.209	0.162	0.146	0.221	80.760
Pastureland	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	0.042	15.457
Cropland	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	0.059	21.581

Table 3-34 Applied TP loading rates for all land use categories used in the Floyds Fork watershed model

TP, lbs/acre/day													Average Loading Rate, lbs/acre/day	Annual Loading Rate, lbs/acre/year
Soil Group: B														
Landuse Category	January	February	March	April	May	June	July	August	September	October	November	December		
Low Intensity Developed, Pervious	0.002	0.002	0.003	0.003	0.004	0.005	0.004	0.004	0.003	0.003	0.002	0.002	0.003	1.078
Medium Intensity Developed, Pervious	0.002	0.002	0.003	0.003	0.004	0.005	0.004	0.004	0.003	0.003	0.002	0.002	0.003	1.089
High Intensity Developed, Pervious	0.001	0.002	0.002	0.002	0.003	0.004	0.003	0.003	0.002	0.002	0.002	0.001	0.002	0.834
Low Intensity Developed, Impervious	0.001	0.002	0.002	0.002	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.002	0.003	1.202
Medium Intensity Developed, Impervious	0.001	0.002	0.002	0.002	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.002	0.003	1.202
High Intensity Developed, Impervious	0.001	0.002	0.002	0.002	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.002	0.003	1.202
All Other Developed, Impervious	0.001	0.002	0.002	0.002	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.002	0.003	1.202
Barren	0.002	0.004	0.004	0.004	0.008	0.008	0.008	0.008	0.008	0.008	0.007	0.004	0.006	2.221
Forest	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.743
Shrub	0.001	0.003	0.003	0.003	0.007	0.007	0.007	0.007	0.007	0.007	0.006	0.003	0.005	1.879
Grassland	0.004	0.024	0.004	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.008	0.004	0.008	3.008
Pastureland	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.931
Cropland	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	3.841
Soil Group: C and D														
Low Intensity Developed, Pervious	0.004	0.006	0.007	0.008	0.009	0.012	0.010	0.009	0.008	0.007	0.006	0.004	0.007	2.695
Medium Intensity Developed, Pervious	0.004	0.006	0.007	0.008	0.009	0.012	0.010	0.009	0.008	0.007	0.006	0.004	0.007	2.722
High Intensity Developed, Pervious	0.003	0.004	0.005	0.006	0.007	0.009	0.008	0.007	0.006	0.005	0.004	0.003	0.006	2.084
Low Intensity Developed, Impervious	0.001	0.002	0.002	0.002	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.002	0.003	1.202
Medium Intensity Developed, Impervious	0.001	0.002	0.002	0.002	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.002	0.003	1.202
High Intensity Developed, Impervious	0.001	0.002	0.002	0.002	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.002	0.003	1.202
All Other Developed, Impervious	0.001	0.002	0.002	0.002	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.002	0.003	1.202
Barren	0.002	0.004	0.004	0.004	0.008	0.008	0.008	0.008	0.008	0.008	0.007	0.004	0.006	2.221
Forest	0.006	0.006	0.006	0.006	0.006	0.007	0.007	0.007	0.007	0.004	0.004	0.006	0.006	2.118
Shrub	0.001	0.003	0.003	0.003	0.007	0.007	0.007	0.007	0.007	0.007	0.006	0.003	0.005	1.879
Grassland	0.047	0.087	0.067	0.091	0.204	0.204	0.204	0.204	0.204	0.073	0.073	0.047	0.125	45.738
Pastureland	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.931
Cropland	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	0.011	3.841

4.0 Watershed Hydrology Model

4.1 Hydrologic Representation

Watershed hydrology plays an important role in the determination of non-point source flow and ultimately non-point source loadings to a waterbody. The watershed model must appropriately represent the spatial and temporal variability of the hydrological characteristics within a watershed. Key hydrological characteristics include interception storage capacities, infiltration properties, evaporation and transpiration rates, and watershed slope and roughness. LSPC's algorithms are identical to those in the Hydrologic Simulation Program FORTRAN (HSPF). The LSPC/HSPF modules used to represent watershed hydrology include PWATER (water budget simulation for pervious land units) and IWATER (water budget simulation for impervious land units). A detailed description of relevant hydrological algorithms is presented in the HSPF (v12) User's Manual (Bicknell et al. 2004).

Initial values for the hydrological parameters were taken from previous work performed on similar hydrogeographic watersheds. The reason behind using previously calibrated model parameters is that they helped to represent the initial physiographic conditions better. However, during the calibration process, model parameters were adjusted, based on local knowledge of soil types and groundwater conditions, within reasonable constraints until an acceptable agreement was achieved between simulated and observed stream flow. Model parameters that were adjusted include: evapo-transpiration, infiltration, upper and lower zone storage, groundwater storage, and losses to the deep groundwater system.

4.2 Observed Flow Data

Short-term USGS flow stations located in the Floyds Fork watershed were used to calibrate and validate the LSPC watershed hydrology model (Figure 4-1). There are a total of 7 USGS flow stations in the Floyds Fork watershed that have an overlapping period of record with the model simulation. Three of the USGS flow stations contained a complete flow record for the simulation period from January 1, 2000 through December 31, 2010, three contained a nearly complete flow record for the simulation period January 1, 2000 through December 15, 2010 and one station contained a flow record for the simulation period January 1, 2000 through September 30, 2002 and from October 1, 2005 through December 31, 2010. Five of the seven stations were used as calibration stations. Three of the calibration stations were located on the main stem of Floyds Fork (USGS 03297900, USGS 03298000 and USGS 03298200) and the other two were on the Chenoweth Run (Lower) (USGS 03298135) and on Pennsylvania Run (USGS 03298300). The remaining two stations (USGS 03298150 and USGS 03298250) were used as validation stations. These stations are shown spatially in Figure 4-1.

Table 4-1 presents the USGS gages utilized for the Floyds Fork watershed and contains the following information: published USGS drainage area, corresponding LSPC sub-watershed, LSPC simulated drainage area, type of station, and the period of record utilized for each gage.

Table 4-1 USGS Flow Gauges used for Calibration and Validation in the Floyds Fork Watershed Model

Location: Main Stem- Floyds Fork							
USGS Gage ID	**Station name**	**USGS Drainage Area (mi^2)**	**USGS Drainage Area (acres)**	**LSPC Sub-Watershed**	**LSPC Drainage Area (acres)**	**Type**	**Period of Record Utilized**
03297900	Floyds Fork near Peewee Valley	80	51136	615	53084	**Calibration**	1/1/2001-12/31/2010
03298000	Floyds Fork at Fisherville	138	88320	180	88803	**Calibration**	1/1/2001-12/31/2010
03298200	Floyds Fork near Mt. Washington	213	136320	606	137052	**Calibration**	1/1/2001-11/30/2010
Location: Tributaries							
03298135	Chenoweth Run at Ruckriegal Parkway	5	3501	167	3449	**Calibration**	1/1/2001-11/30/2010
03298150	Chenoweth Run at Gelhaus Lane	12	7424	609	8176	**Validation**	1/1/2001-12/31/2010
03298250	Cedar Creek at Thixton Road	11	7104	134	7212	**Validation**	1/1/2001-9/30/2002, 10/1/2005-12/31/2010
03298300	Pennsylvania Run at Mt. Washington	6	4096	130	4182	**Calibration**	1/1/2001-11/30/2010

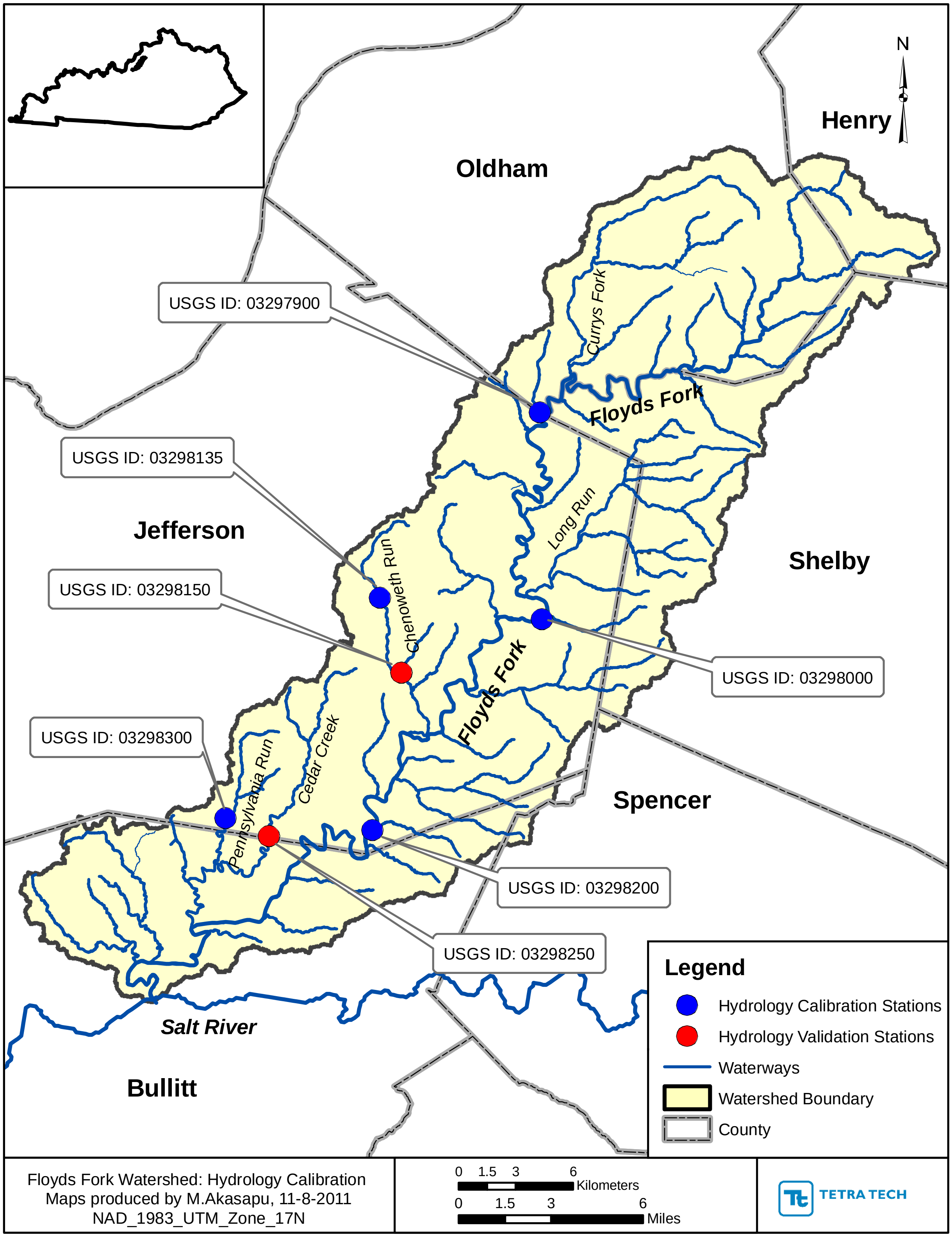


Figure 4-1 Calibration and Validation Stations used in the Hydrology Model

4.3 Hydrology Model Calibration

The calibration of the LPSC watershed hydrology model involved comparing simulated stream flows to five USGS flow stations. The calibration of the hydrologic parameters was performed from January 1, 2001 through December 31, 2010. Results of the model calibrations are presented in Appendix A.

4.4 Hydrology Model Validation

An important step of the modeling process is model validation. Model validation is the process of taking the hydrological parameters that have been calibrated, applying those parameters to other watersheds, and comparing the simulated flow to measured flow from a USGS stream gauging station for the same period of time. Model validation is sometimes called model verification, as essentially the model is being validated or verified with the hydrological parameters calibrated in one watershed to produce acceptable results in another watershed. It is important that when selecting watersheds to perform validations, those watersheds represent a wide variety of land uses as well as drainage areas. This will help to ensure that the hydrological parameters that were calibrated apply to a wide range of conditions. Validation of the hydrologic parameters was performed by comparing simulated flow data to measured data collected at two separate USGS flow gages. The validation of the hydrological parameters was performed from January 1, 2001 through December 31, 2010 for USGS 03298150 and from January 1, 2001 through September 30, 2002 and from January 1, 2006 through December 31, 2010 for USGS 03298250. Results of the model validation are also presented in Appendix A.

4.5 Hydrology Observations and Conclusions

For the hydrology calibration, the observed and simulated flows were analyzed based on a quantitative statistical analysis. There are 9 volume based metrics that were evaluated for the calibration. They are: Total Volume, 50% Lowest Flows, 10% Highest Flows, Seasonal Volume for Summer, Fall, Winter and Spring, Storm Volumes and Summer Storm Volumes. Based on the quantitative scores and validation of the model, the model performs very well.

Two of the flow stations on the main stem of Floyds Fork were over predicting the base flows (USGS 03297900 and USGS 03298000). However, the base flow on the downstream most flow station on the main stem lost this excess flow and was well within the metric for 50% lowest flows. A similar trend was observed on the flow stations located on Chenoweth Run (Lower). The upstream flow station is under predicting the base flow and the flows estimated downstream of this station are well within the range of this metric. The under prediction of base flows for the station on Chenoweth Run (Lower) was attributed to the location of these stations which occur in areas identified as having minor karst development. It could be theorized that the karst flow channel was adding/removing the flows to/from the system. After springs were identified upstream of this flow station, the under prediction of the base flows was corrected. The metrics of this flow station and the station downstream of it were all within the range. The USGS flow station on the Chenoweth Run (Lower) (USGS 03298135) was located in a heavily impervious area and was responding differently to the adjusted parameters compared to the rest of the stations. During the calibration process, a large amount of work was put into making this gage better. Adjustments to this gage were made judiciously to make sure that they would not impact other stations in the watershed negatively.

A qualitative grading scale (VG=Very Good, G=Good, F=Fair, and P=Poor) was developed based on the quantitative statistical analysis. Table 4-2 shows the period of record quantitative statistical analysis for gage USGS 03298200. The numbers in the column "Error Statistics" were utilized to calculate a score based on their deviation from zero with zero meaning that simulated and observed are equal. The column "Recommended Criteria" is the USGS recommended maximum deviation (+/-) of simulated and observed flows for acceptable calibration of a watershed model. The flow summary types are also in ascending order of those easiest to hardest to obtain. An example of the grading technique is discussed in detail below.

Period of record error statistics have been placed in the model stat column in Table 4-3. For each flow summary statistic, the absolute value of the model statistic is compared against the values in columns VG, G, F and P. If the value is less than VG then it is given a value of 4, if less then G but greater than VG it is given a value of 3, if less then F but greater than G it is given a value of 2, and if it is greater than P it is given a value of 1 (Table 4-4). The assigned value of the flow summary statistic is multiplied by the weight to produce a score for each flow summary type. Flow summary types have been assigned a weight based on their overall importance for a successful calibration. The error in total volume is most important followed by the errors in the high and low flows, then the error in seasonal volumes and finally the errors in storm volumes. The score for the flow summary statistics are then summed to produce a total score for each gage. This total score is then compared against the minimum score for each qualitative grade (Table 4-5) and the grade assigned.

Table 4-2 Summary Statistics: Model Outlet 606 vs. USGS 03298200 Floyds Fork Near Mt. Washington, KY

LSPC Simulated Flow		Observed Flow Gage		
REACH OUTFLOW FROM SUBBASIN 606 9.91-Year Analysis Period: 1/1/2001 - 11/30/2010 Flow volumes are (inches/year) for upstream drainage area		USGS 03298200 FLOYDS FORK NEAR MT WASHINGTON, KY Hydrologic Unit Code: 5140102 Latitude: 38.08534216 Longitude: -85.5549556 Drainage Area (sq-mi): 213		
Total Simulated In-stream Flow:	**20.91**	Total Observed In-stream Flow:		**22.53**
Total of simulated highest 10% flows:	**12.63**	Total of Observed highest 10% flows:		**13.49**
Total of Simulated lowest 50% flows:	**1.47**	Total of Observed Lowest 50% flows:		**1.57**
Simulated Summer Flow Volume (months 7-9):	**3.02**	Observed Summer Flow Volume (7-9):		**2.62**
Simulated Fall Flow Volume (months 10-12):	**5.90**	Observed Fall Flow Volume (10-12):		**5.44**
Simulated Winter Flow Volume (months 1-3):	**6.07**	Observed Winter Flow Volume (1-3):		**7.87**
Simulated Spring Flow Volume (months 4-6):	**5.92**	Observed Spring Flow Volume (4-6):		**6.60**
Total Simulated Storm Volume:	**12.41**	Total Observed Storm Volume:		**13.71**
Simulated Summer Storm Volume (7-9):	**1.95**	Observed Summer Storm Volume (7-9):		**1.92**
Errors (Simulated-Observed)	*Error Statistics*	*Recommended Criteria*		
Error in total volume:	-7.18	10		
Error in 50% lowest flows:	-6.58	10		
Error in 10% highest flows:	-6.38	15		
Seasonal volume error - Summer:	15.10	30		
Seasonal volume error - Fall:	8.36	30		
Seasonal volume error - Winter:	-22.81	30		
Seasonal volume error - Spring:	-10.23	30		
Error in storm volumes:	-9.54	20		
Error in summer storm volumes:	1.73	50		
Nash-Sutcliffe Coefficient of Efficiency, E:	0.698	Model accuracy increases		
Baseline adjusted coefficient (Garrick), E':	0.549	as E or E' approaches 1.0		

Table 4-3 Qualitative Grading Scale for USGS 03298200 Floyds Fork Near Mt. Washington

Flow Summary Type	VG	G	F	P	Weight	Model Stat	Model Stat Ab. Val	Score		
Error in total volume	10	15	20	25	4	-7.18	7.18	16	Score	80
Error in 50% lowest flows	10	15	20	25	3	-6.58	6.58	12	Grade	VG
Error in 10% highest flows	15	20	25	30	3	-6.38	6.38	12		
Seasonal volume error - Summer	30	40	50	60	2	15.10	15.10	8		
Seasonal volume error - Fall	30	40	50	60	2	8.36	8.36	8		
Seasonal volume error - Winter	30	40	50	60	2	-22.81	22.81	8		
Seasonal volume error - Spring	30	40	50	60	2	-10.23	10.23	8		
Error in storm volumes	20	30	40	50	1	-9.54	9.54	4		
Error in summer storm volumes	50	60	70	80	1	1.73	1.73	4		

Table 4-4 Potential Scores Based on Qualitative Grade and Weighting Factor

Error	VG	G	F	P	Weight	VG Score	G Score	F Score	P Score
Error in total volume	4	3	2	1	4	16	12	8	4
Error in 50% lowest flows	4	3	2	1	3	12	9	6	3
Error in 10% highest flows	4	3	2	1	3	12	9	6	3
Seasonal volume error - Summer	4	3	2	1	2	8	6	4	2
Seasonal volume error - Fall	4	3	2	1	2	8	6	4	2
Seasonal volume error - Winter	4	3	2	1	2	8	6	4	2
Seasonal volume error - Spring	4	3	2	1	2	8	6	4	2
Error in storm volumes	4	3	2	1	1	4	3	2	1
Error in summer storm volumes	4	3	2	1	1	4	3	2	1
Sum						80	60	40	20

Table 4-5 Score Minimum and Corresponding Qualitative Grade

Grade	VG	G	F	P
Score Minimum	75	55	35	20

Table 4-6 shows the score and grade for each of the USGS flow gages utilized in the Floyds Fork watershed model. The summary provided in Table 4-6, along with the other visual and statistical summaries in Appendix A indicate that the hydrology model will perform well for the intended purpose of approximating watershed flows for the Floyds Fork watershed. The quantitative scores of these flow stations are shown spatially in Figure 4-2.

Table 4-6 Score and Grade for USGS flow gages utilized in the Floyds Fork Watershed model

Location: Main Stem- Floyds Fork			
USGS Gage ID	Station name	Qualitative Score	Quantitative Score
03297900	Floyds Fork near Peewee Valley	VG	77
03298000	Floyds Fork at Fisherville	VG	80
03298200	Floyds Fork near Mt. Washington	VG	80
Location: Tributaries			
03298135	Chenoweth Run at Ruckriegal Parkway	VG	77
03298150	Chenoweth Run at Gelhaus Lane	VG	80
03298250	Cedar Creek at Thixton Road	G	67
03298300	Pennsylvania Run at Mt. Washington	G	73

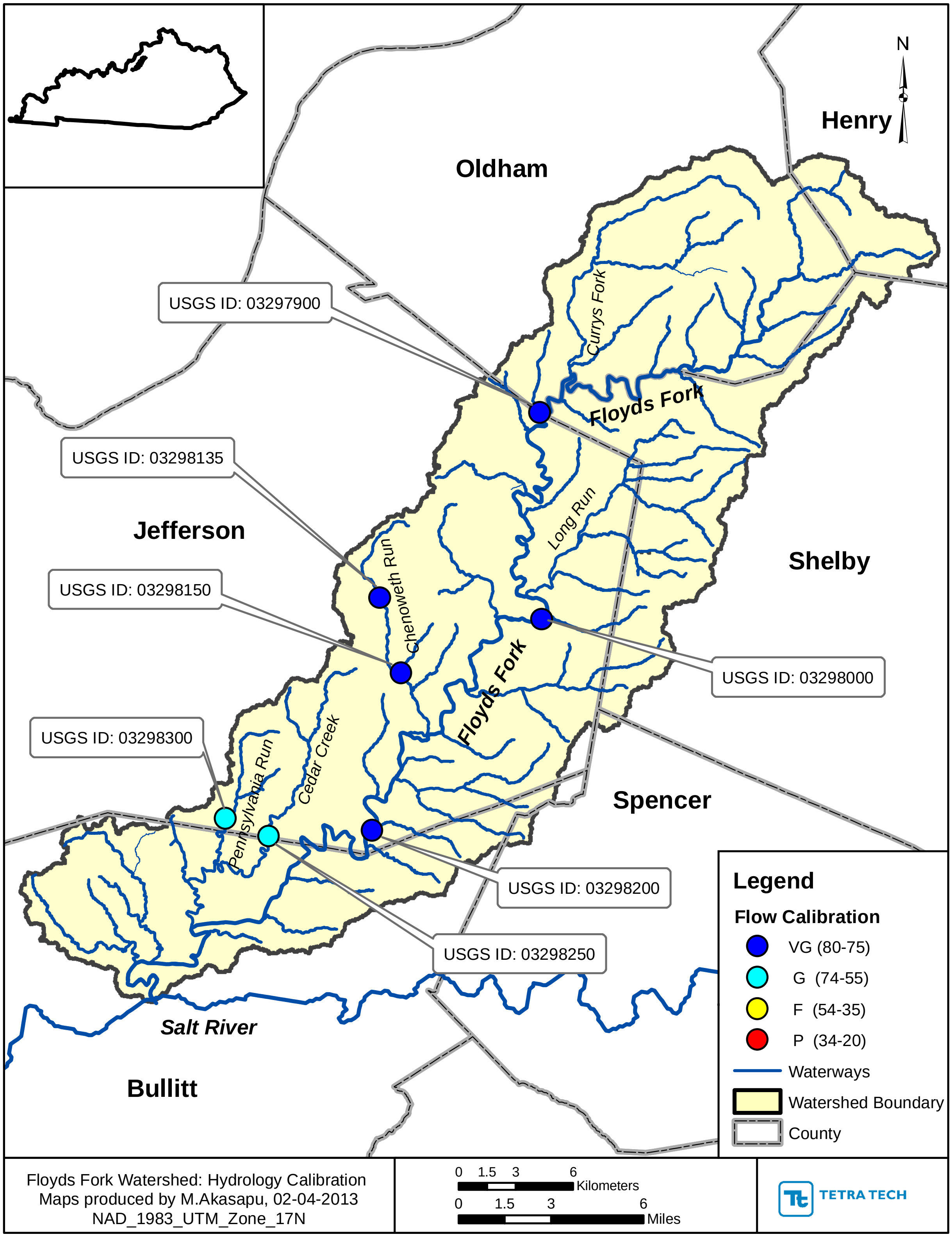


Figure 4-2 Hydrology Calibration in the Floyds Fork Watershed

5.0 Watershed Water Quality Model

5.1 Water Quality Model Overview

Once the LSPC watershed hydrology model was calibrated, the model was used to create a water quality model of the Floyds Fork watershed. Many components of the water quality model were established during hydrology modeling. These components included watershed segmentation, meteorological data, land use representation, soils, reach characteristics, and point source discharges. The watershed water quality model included all point and non-point source contributions. Nutrient loadings from point sources were represented by developing direct input time series, for each point source, using discharge monitoring report data. Non-point source nutrient loadings were represented by build-up and wash off algorithms and assigning nutrient concentrations to the interflow and groundwater flow paths. Nutrients in the stream experienced dilutions, accumulations, assimilation, biochemical cycling, and transport to downstream and out of the watershed.

5.2 Modeled Parameters

The LSPC water quality model was setup to model Temperature, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Total Nitrogen (TN), Total Phosphorus (TP), and Total Suspended Solids (TSS).

5.3 Reach Group

For in-stream water quality simulation, the user has the ability to model in-stream processes for the reaches by assigning them to reach groups. Reaches were assigned into reach groups based on the Strahler stream order number. The Strahler stream order system classifies the stream segments based on the number of tributaries upstream of it. A headwater stream (stream with no tributaries) is considered first order stream. A stream located downstream of the confluence of two first order streams is a second order stream (Strahler 1957). Assigning reaches into groups allows for the assignment of unique values for each reach group for certain LSPC parameters.

The parameters that can be assigned differently by reach group include: sediment bed storage parameters, cohesive and non-cohesive suspended sediment variables for in-stream transport, temperature for stream groups, bed heat conduction parameters, land to stream mapping, variables associated with BOD sinking, decay, and benthic release, variables for dissolved oxygen reaeration, benthic oxygen demand, and oxygen scour. In LSPC, reach group is analogous to the RCHRES block in HSPF. A detailed description of relevant in-stream and transport algorithms is presented in the HSPF (v12) User's Manual (Bicknell et al. 2004).

5.4 Water Temperature

In-stream temperature is an important parameter for simulating biochemical transformations. LSPC models in-stream temperatures by using algorithms identical to those in the Hydrologic Simulation Program FORTRAN (HSPF). The LSPC/HSPF modules used to represent water temperature include PSTEMP (soil temperature) and HTRCH (heat exchange and water temperature). A detailed description of relevant temperature algorithms is presented in the HSPF (v12) User's Manual (Bicknell et al. 2004).

Soil temperature is only used to determine the water temperature of the three different flow paths (surface outflow, upper subsurface/interflow outflow, lower subsurface/groundwater outflow) contributing to stream flow. Once the water is in the stream, the temperature is impacted by mechanisms that can increase or decrease the heat content of the water. Mechanisms which can increase the heat content of the water are absorption of solar radiation, absorption of long-wave radiation, and conduction-convection. Mechanisms which decrease the heat content are emission of long-wave radiation, conduction-convection and evaporation (Bicknell et al. 2004).

For the calibration of water temperature, the existing reach geometry became an important parameter. The reach bank full depth for most of the headwater sub-watersheds were close to or in many cases less than 1.92″, forcing the in-stream temperature to be equal to the ambient air temperature. In order to simulate the in-stream temperatures better, the reach bank full widths and the reach ratio of bottom width to bank full width (r1) corresponding to these sub-watersheds was decreased. This forced the reach bank full depths to be greater than 1.92″.

5.5 Dissolved Oxygen

Dissolved oxygen concentration is generally viewed as an indicator of the overall well-being of streams or lakes and their associated ecological systems. In relatively unpolluted waters, sources and sinks of oxygen are in approximate balance and the concentration remains close to saturation. By contrast, in a stream receiving untreated waste waters, the natural balance is upset, bacteria predominate, and a significant depression of DO results (Bicknell et al. 2004).

LSPC models in-stream DO by using algorithms identical to those in the Hydrologic Simulation Program FORTRAN (HSPF). The LSPC/HSPF module used to represent DO include PWTGAS (pervious water temperature and dissolved gas concentrations), IWTGAS (impervious water temperature and dissolved gas concentrations), and OXRX (primary DO and BOD balances). A detailed description of relevant temperature algorithms is presented in the HSPF (v12) User's Manual (Bicknell et al. 2004).

Setting aside in-stream transformations, which either consume or produce DO, a major player in the DO concentration is stream temperature. It is well known that colder water can dissolve more gas than warmer water. Another major player is atmospheric reaeration. Atmospheric reaeration takes into consideration the DO concentration to start with, oxygen saturation level for a given water temperature, water depth, water velocity, circulation, reaeration rate, and a temperature correction coefficient for surface gas invasion. LSPC allows for user defined DO concentrations in interflow and groundwater by land use and month.

The BOD decay and settling parameterization is important in the process of reaeration (Bicknell et al. 2004). The BOD decay rate at 20°C (KBOD20) was an important calibration parameter for capturing the DO processes. This parameter was set lower for headwater sub-watersheds and higher for non-headwater sub-watersheds because shallower and narrower streams are expected to decay faster than deeper and wider streams.

5.6 Sediment

LSPC models sediment by using algorithms identical to those in the Hydrologic Simulation Program FORTRAN (HSPF). The LSPC/HSPF module used to represent sediment include SEDMNT (pervious production and removal of sediment), SOLIDS (accumulation and removal of solids), and SEDTRN (behavior of inorganic sediment). A detailed description of relevant sediment algorithms is presented in the HSPF (v12) User's Manual (Bicknell et al. 2004).

Sediment is one of the most difficult water quality parameters to accurately simulate with watershed models. The approach to modeling sediment in the Floyds Fork watershed consisted of starting with the final calibrated parameter values generated during the previous work performed on similar watersheds and then adjusting the parameters in accordance with guidelines established in EPA BASINS Technical Note 8 Sediment Parameters and Calibration guidance to HSPF (EPA, 2006) and Sediment Calibration Procedures and Guidelines for Watershed Modeling (Donigian et al. 2003), to represent the local conditions better.

A detailed description of relevant sediment algorithms is presented in the HSPF (v12) User's Manual (Bicknell et al. 2004). Key processes for sediment include: soil detachment, soil compaction, fraction of land use shielded from rain drop impact, sediment washoff rate, and in-stream transport which includes settling velocities and flow velocities that contribute to deposition and re-suspension of sediment particles.

5.7 Nutrients

LSPC models nutrients by using algorithms identical to those in the Hydrologic Simulation Program FORTRAN (HSPF). The LSPC/HSPF module used to represent nutrients include PQUAL (quality constituents using simple relationships) and IQUAL (wash-off of quality constituents using simple relationships). A detailed description of relevant nutrient algorithm is presented in the HSPF (v12) User's Manual (Bicknell et al. 2004).

Accumulation and wash-off rates play an important role in the determination of non-point source loadings to a waterbody. The watershed model must appropriately represent the spatial and temporal variability of hydrological characteristics within a watershed. It must also appropriately represent the rate at which nutrient components build-up between rain events and wash off during rain events. Key general water quality characteristics include initial storage, wash-off and scour potency, accumulation rates, and maximum storage amounts. The water supplied to a stream from groundwater and through interflow also plays an important role in loading to a waterbody. LSPC allows the user to supply groundwater and interflow concentrations, by hydrologic soil group and land use, by month. The accumulation and wash-off and interflow strongly influence peak flow water quality while groundwater reflects base flow water quality.

Biochemical in-stream processes play an important role on nutrient concentrations spatially and temporally. Biochemical processes also has a large influence on DO and ultimately water quality. The watershed model should appropriately represent some of the major biochemical processes occurring within in the stream, including DO and biochemical oxygen demand balances, organic and inorganic nutrient balances. In order to accurately represent biochemical processes, temperature must be modeled because all transformation rates are temperature dependent. Key processes for oxygen include: benthic oxygen demand, sinking and benthic release of BOD material, reaeration, and oxygen depletion due to decay of BOD. Key processes for nutrients include: buildup and washoff rates, interflow and groundwater concentrations and rate of surface runoff that removes 90% of stored nutrient (WSQOP).

5.8 Water Quality Development and Calibration

Temperature was the constituent calibrated after hydrology because the remaining parameters use water temperature in their algorithms. Temperature was calibrated by adjusting the widths of the reaches, the correction factor for solar radiation and the water-ground heat conduction coefficients, by reach group, until the simulated data captured the trend of the observed data. After temperature was calibrated, DO was brought into close agreement with the observed data by adjusting reaeration coefficients, BOD decay rate and benthic oxygen demand. At this point DO was only partially calibrated because the water quality simulation was only partially active. Next, the sediment module was turned on and the parameters used were adjusted until the simulated data closely matched the observed data. After the above three modules were either calibrated or brought into reasonable agreement, the calibration process turned to nutrients.

The first step in nutrient calibration involved looking at BOD, TN, and TP. These three constituents were modeled by build-up/wash-off and assigning land use associated concentrations in groundwater and interflow. Build-up/wash-off removes constituents from the land and carries them into the stream. The loading rates from fertilizer and manure and from golf courses are tabulated in Table 3-24 and 3-25 respectively and were applied to the model as monthly accumulation rate (MON-ACCUM) for Cropland, Pastureland, and Grassland. The loading rates for all other land uses were taken from initial values and were adjusted to better simulate local conditions. The land uses associated with sinkholes were assigned the same loading rates as their respective land use. Adjustments were made to monthly accumulation rate, monthly storage limit, interflow concentration, and groundwater concentration for BOD, TN, and TP until the simulated data was in range with the observed field data.

Once the build-up/wash-off rates were close, decay rates became the last step in calibrating the watershed model for nutrients. Decay rates were calibrated by balancing DO and in-stream nutrient concentrations. For example, if a modeled parameter is simulating too high and DO was simulated low then a change was made to reduce the BOD decay rate. This change will decrease the modeled constituent and also increase the DO because not as much of the constituent is being decayed, therefore decreasing the amount of DO consumed.

5.9 Septic Tanks

To represent the contribution of water quality from non-failing septic tanks, literature concentration data was used (Gerner 2004, Lihua 2002, Jones 2005). It was assumed that each septic tank serves a household of 2.8 people, each person accounts for 70 gallons/day of water use and 15% of the water used in the house never makes it to the septic tank. It was also assumed that it takes an average of 60 days for the septic flow to reach a body of water, so a first order decay rate was applied to each constituent to determine the concentration after 60 days. Table 5-1 presents the concentration of septic tank effluent, decay rates for each parameter, and the concentration after 60 days of decay. For phosphorus, it was also assumed that 90% of it was sorbed to sediment; therefore only 10% of the effluent concentration was used to calculate decay after 60-days. Non-Failing septic tank data was developed into a direct input time-series and in the computational domain is handled like a point source.

For failing septic tank land use loading representation, effluent loadings were obtained from literature (USEPA 2002) and are shown in Table 5-2. Septic tank loadings were allowed to accumulate on the land for a period of 5-days before reaching the maximum storage value.

Table 5-1 Non-Failing Septic Tank Water Quality Concentrations

Parameter	Effluent Concentration (mg/l)	Decay Rate (1/day)	Concentration at Stream (mg/l)**
BOD5	105	0.16	0.003
Total Nitrogen	70.258	0.1	0.1263
Organic Nitrogen	0.458	0.1	0.0008
Ammonia	10.5	0.1	0.0189
Nitrate_Nitrite	59.3	0.1	0.1066
Total Phosphorus*	0.3	0.014	0.1287
Organic Phosphorus*	0.3	0.014	0.1287
Ortho-Phosphorus*	0	0.014	0
TSS	10	0	10
Dissolved Oxygen	--	--	4
WTEM	--	--	GW Temp***

*It was assumed that 90% of phosphorus is sorbed to sediment
**Assumes Septic Flow takes an average of 60 days to reach stream
***Supplied groundwater temperature from temperature component of simulation

Table 5-2 Failing Septic Land Use Nutrient Loading Rates

Parameter	Effluent Loading (lbs/acre/day)
BOD5	0.309
Total Nitrogen	0.070
Total Phosphorus*	0.009

* It was assumed that 90% of Phosphorus is sorbed to sediment

5.10 Observed Water Quality Data Calibration and Validation

During the simulation period, water quality observations were approximately collected every month at 26 USGS stations within the Floyds Fork watershed. The primary period of data collection was from 2007 through 2008. A majority of the USGS stations were located on the western side of the Floyds Fork watershed which was dominated by point sources and urban land use. From 2000 through 2010, Jefferson County MSD collected water quality data at five stations within the Floyds Fork watershed. Three out of the 5 MSD stations were located on the main stem of Floyds Fork (EFFFF001, EFFFF002 and EFFFF003) and the remaining 2 stations on Chenoweth Run (Lower) (EFFCR001 and EFFCR002).

Data collected at the USGS stations included Temperature, DO, pH, Ammonia (NH_3), Nitrate+Nitrite (NO_X), Total Kjeldahl Nitrogen (TKN), TP, Orthophosphate (PO_4), BOD_5, TSS, Conductivity and Turbidity. At the MSD stations, data was collected on Temperature, DO, pH, NH_3, NO_X, TKN, TP, PO_4, BOD_5, TSS, Conductivity and Hardness.

All 26 USGS stations were used as calibration stations and the 5 MSD stations were used as validation stations. The 5 MSD stations are located in the same location as the 5 USGS calibration stations (USGS 03297900-EFFFF001, USGS 03298200-EFFFF002, USGS 03298000-EFFFF003, USGS 03298150-EFFCR001 and USGS 03298135-EFFCR002).

Figures 5-1, 5-2 show the location of the USGS and MSD water quality stations respectively. Table 5-3 tabulates the USGS calibration and the MSD validation stations.

Table 5-3 Water Quality Calibration and Validation Stations used in the Floyds Fork Watershed

Water Quality Station location: Main Stem- Floyds Fork			
USGS Station ID	**Station name**	**Agency**	**Type**
03297830	Floyds Fork at Highway 53	USGS	Calibration
03297845	Floyds Fork near Crestwood	USGS	Calibration
03297900	Floyds Fork near Peewee Valley	USGS	Calibration
03297930	Floyds Fork at Echo trail bridge	USGS	Calibration
03298000	Floyds Fork at Fisherville	USGS	Calibration
03298120	Floyds Fork at Seatonville Road	USGS	Calibration
03298200	Floyds Fork near Mt. Washington	USGS	Calibration
03298470	Floyds Fork near Shepherdsville	USGS	Calibration
EFFFF001	Floyds Fork at Ash Avenue	MSD	Validation
EFFFF002	Floyds Fork at BardStown Road	MSD	Validation
EFFFF003	Floyds Fork at Old Taylorsville Road	MSD	Validation
Water Quality Station location: Tributaries			
03297850	South Fork Curry's Fork at Moody Lane	USGS	Calibration
03297855	South Fork Curry's Fork at Highway 393	USGS	Calibration
03297860	North Fork Curry's Fork at Stone Ridge road	USGS	Calibration
03297875	Ashers Run at Abbott lane near Crestwood	USGS	Calibration
03297880	Currys Fork near Crestwood	USGS	Calibration
03297950	Long Run at Old stage coach road	USGS	Calibration
03297975	South Long Run at Hobbs Lane	USGS	Calibration
03297980	Long Run near Fisherville	USGS	Calibration
03298005	Pope lick at South poope lick road near Fisherville	USGS	Calibration
03298020	Chenoweth Run at Gelhaus Lane	USGS	Calibration
03298100	Pope lick at pope lick road near Middletown	USGS	Calibration
03298110	Pope lick at Rehl road near Fisherville	USGS	Calibration
03298135	Chenoweth Run at Ruckriegal Parkway	USGS	Calibration
03298138	Chenoweth Run at Jeffersontown STP at Jeffersontown	USGS	Calibration
03298150	Chenoweth Run at Gelhaus Lane near Fern creek	USGS	Calibration
03298160	Chenoweth Run at Seatonville road near Jeffersontown	USGS	Calibration
03298250	Cedar Creek at Thixton Road	USGS	Calibration
03298300	Pennsylvania Run at Mt. Washington	USGS	Calibration
EFFCR001	Chenoweth Run # 1 at Gelhaus Lane	MSD	Validation
EFFCR002	Chenoweth Run # 1 at Rickriegal Parkway	MSD	Validation

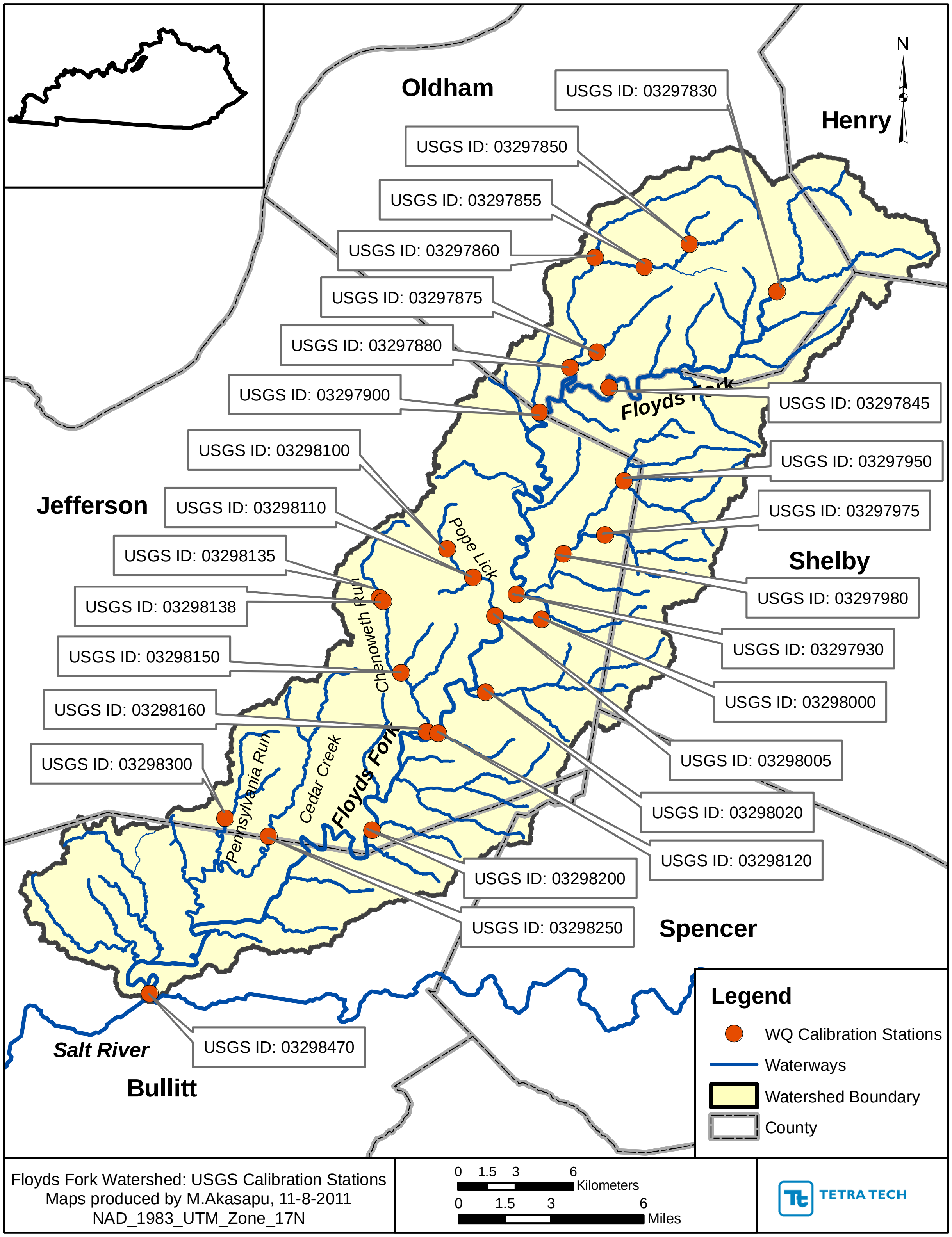


Figure 5-1 USGS Calibration Stations used in the Water Quality Model

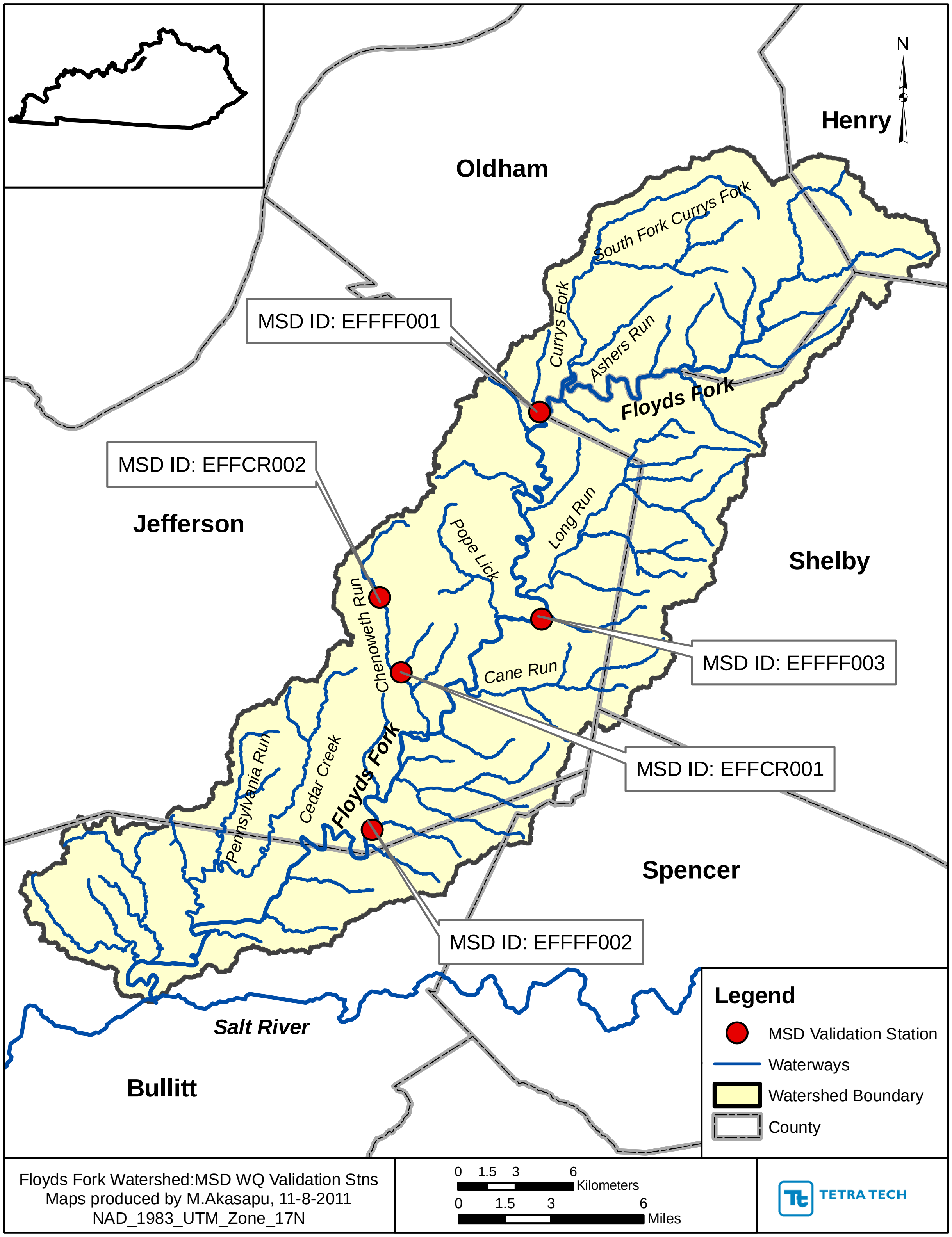


Figure 5-2 MSD Validation Stations used in the Water Quality Model

5.11 Water Quality Observations and Conclusions

The LSPC model simulated temperature very well at all calibration and validation stations. The model captured the highs and lows of the seasonal variations very well at all USGS calibration stations and at two of the 5 MSD validation stations (EFFCR001 and EFFFF003). The temperature simulation for the remaining 3 validation stations (EFFCR002, EFFFF001 and EFFFF002) matched very well in terms of magnitude but the data appeared shifted by 2-3 months. Overall the LSPC model calibration for temperature is very good.

The LSPC model simulated DO fairly well at all calibration stations and at two of the MSD validation stations on Chenoweth Run (Lower). This was expected since temperature and DO concentrations are highly correlated with one another. There were a few locations where the LSPC model did not have low enough DO concentrations in the summertime or high enough DO concentrations during wintertime. This trend was observed at water quality stations dominated by agricultural land. This could be attributed to localized oxygen demands or low velocities which are not advantageous for DO reaeration. This could also be due to the limited data with only 2 years available for calibration. Generally speaking, the LSPC model calibration for DO is good.

It has been well documented that sediment loading from the land occurs during very intense rain events. Because of this fact and also because of infrequent sampling events during low-flow/low-rain events, sediment was a difficult parameter to calibrate. At all of the USGS calibration stations the model properly captured the trends and the magnitudes of the sediments during low flow events. The peaks at high flow events were also captured well. The model simulated low suspended sediment concentrations almost all of the time except for when rain events came through and washed some sediment into the streams. Without having monitored data during these times of sediment delivery to the stream, it was hard to determine how well the model is calibrated for sediment.

Much of the monitored BOD data was very near or below the method detection limit of 5 mg/l. With this in mind, the goal was to try to simulate BOD concentrations at around 5 mg/l. The model does a fairly good job at simulating BOD when concentrations are less than 5 mg/l.

TN and TP were also simulated fairly well. The focus of the watershed model calibration for TN and TP was to properly represent the magnitudes and to capture the trends of the nutrients entering Floyds Fork. Similar trends were observed for water quality stations dominated by non-point sources and those dominated by point sources. All the stations unaffected by point sources were calibrated very well in capturing the trends and magnitudes of the nutrients. However, there were a few stations in this category that did not capture the nutrient loads as well as the rest. This could be attributed to the measured flow data used for these stations. The water quality stations dominated significantly by point sources often resulted in higher concentrations than the measured data, though they did capture the trends well. This was especially true for TP. The effect of the point source impacts at the calibrations stations could be attributed to the resolution of the point source concentrations or because of the measured flow data being low for the estimated loads.

By comparing the simulated and observed data at the downstream most Floyds Fork water quality station (USGS 03298470), it could be concluded that the model does pretty well at capturing both the magnitude and seasonal variability of TN and TP. Below (Figures 5-3 through 5-6) are the plots showing paired comparisons of simulated and observed measurements and annual box and whisker plots at the station located on the Floyds Fork near Shepherdsville as it enters the Salt River.

Paired comparison means that on any day that an observation was recorded it was compared with the simulated average daily concentration. Both the observed and simulated concentrations were converted to pounds per day by utilizing observed and simulated flow respectively. The observed data was from the USGS station at that location. Figure 5-3 and 5-4 suggests that the model is slightly over predicting the nutrients. However, the plots also indicate that for TN and for TP, the comparison between the observed and simulated values is good because the cluster of data is concentrated fairly close to the center of the line.

Box and Whisker plots (Figure 5-5 and 5-6) are another graphical way of analyzing measured and modeled data and the distribution of key statistics for both. It is based on the median of measured and modeled data. It helps depict the data through: smallest observation, lower quartile, median, upper quartile and the largest observation. The median for modeled TN and TP is fairly close to the measured TN and TP median. This suggests that the simulation of nutrients is good.

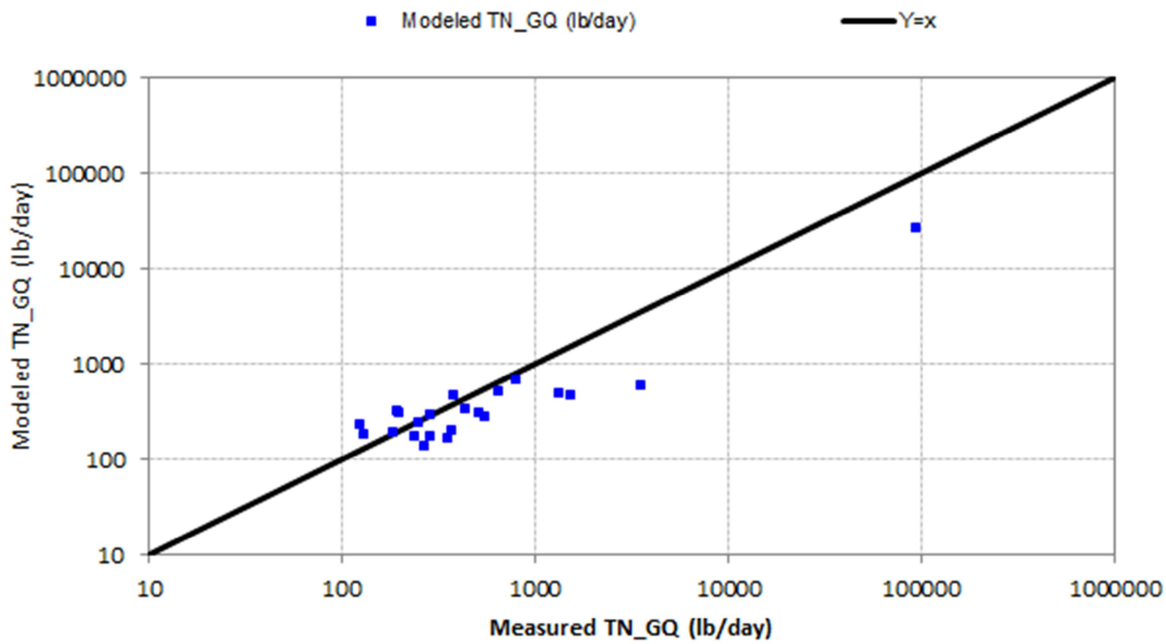


Figure 5-3 USGS 03298470 Modeled vs Observed paired comparison for Total Nitrogen

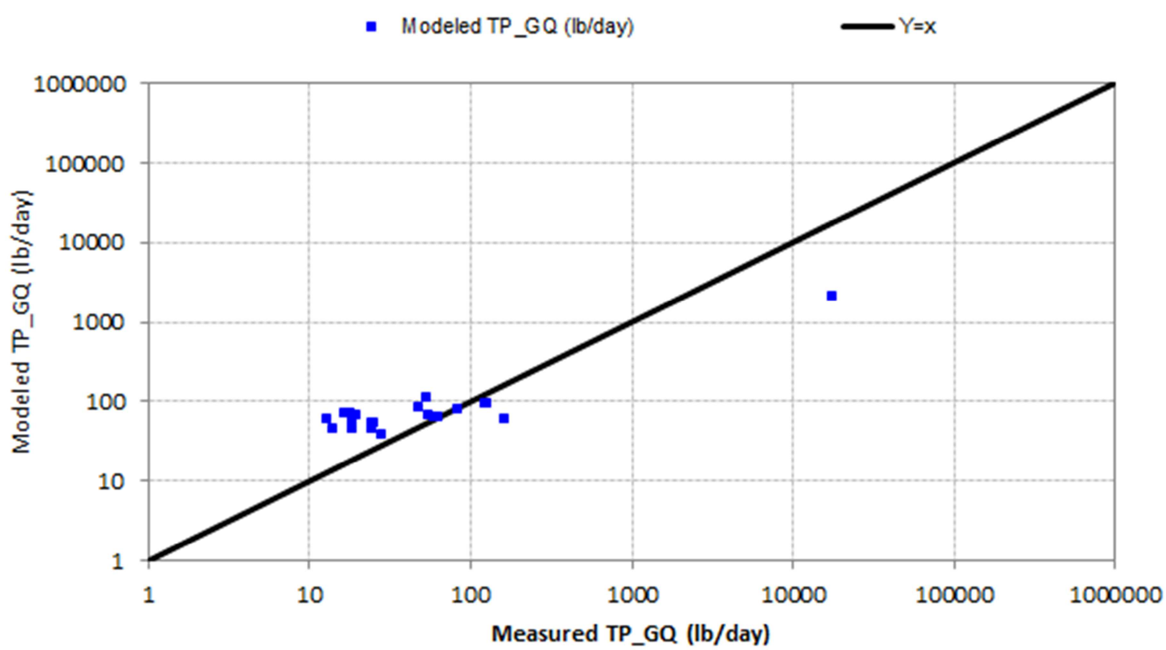


Figure 5-4 USGS 03298470 Modeled vs Observed paired comparison for Total Phosphorus

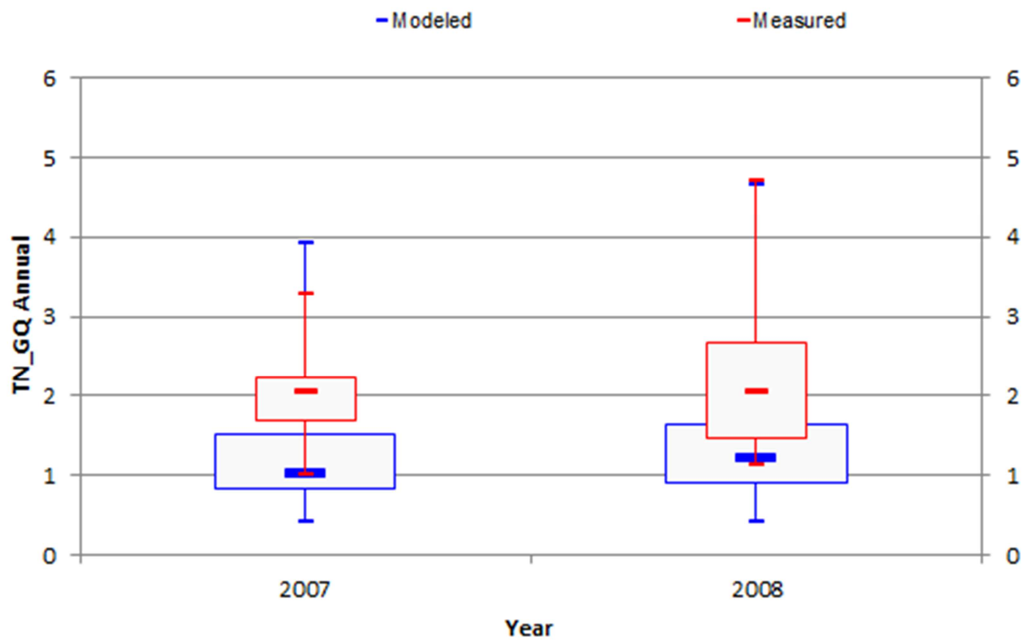


Figure 5-5 USGS 03298470 Modeled vs Observed Annual Box and Whisker plot for Total Nitrogen

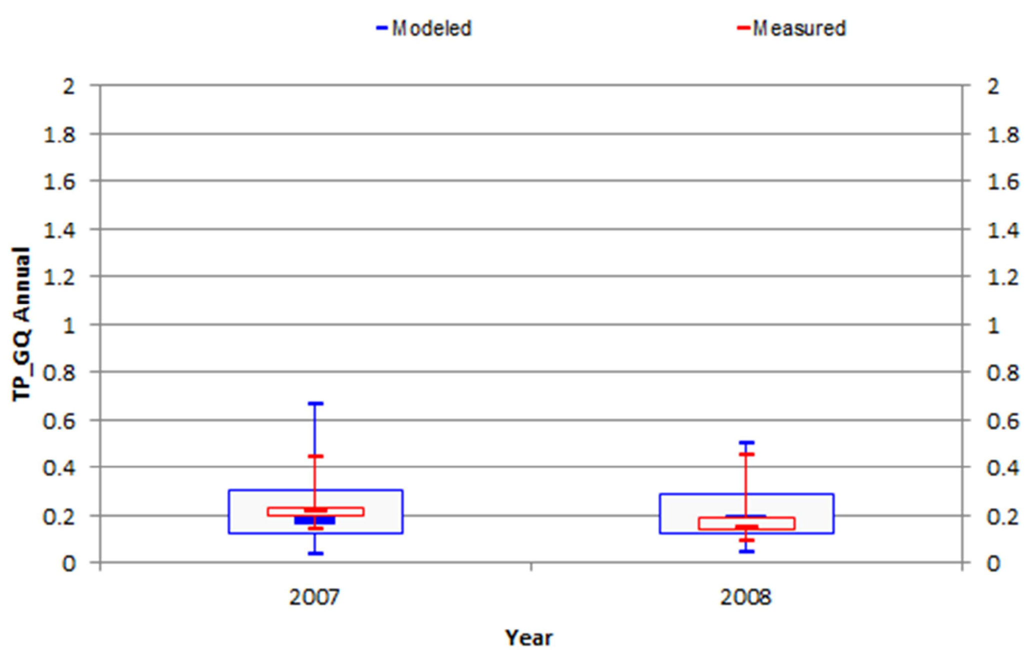


Figure 5-6 USGS 03298470 Modeled vs Observed Annual Box and Whisker plot for Total Phosphorus

Similar to hydrology, a qualitative grading rank (VG=Very Good, G=Good, F=Fair, and P=Poor) was developed. The ranking was based on a quantitative analysis of simulated versus observed loads developed in the spreadsheet utilized for calibrating and validating watershed water quality models. However, unlike hydrology, the water quality qualitative grading rank utilized the annual load differences between measured and simulated loads for the average period of record and compared it against the criteria defined for the water quality calibration. For further explanation, an example of the grading technique is provided in detail below for TP at USGS station 03298200.

The average annual 'Modeled' and Measured' loads for the Nutrients were computed for the period of record (Table 5-4). The absolute percentage error was then estimated and compared with the values found in Table 5-5. A qualitative grade was then assigned based on the calculated absolute percentage error. For this example, the absolute percentage error for TP during the period of record was calculated to be 14. Because 14 is less than 30, which is the criterion for a very good ranking, TP at USGS station 03298200 received the maximum qualitative grade of very good. Table 5-5 shows the range of absolute percentage error criteria established for Nutrients. For a 'very good' score, nutrient error needs to be within 30%.

Table 5-6 shows the score and grade for each of the USGS water quality calibration stations and MSD validation stations. The summary provided in Table 5-6, along with the other visual and statistical summaries in Appendix B indicate that the Water Quality model should perform reasonably well for the intended purpose of approximating nutrient loads in Floyds Fork. The quantitative scores of the USGS stations for TN and TP are shown spatially in Figure 5-7 and 5-8 respectively. The quantitative scores of the MSD stations for TN and TP are shown spatially in Figure 5-9 and 5-10 respectively.

Table 5-4 Measured and Simulated TP Loads for USGS 03298200

Year	Total Phosphorus (lbs/yr)			Score	Ranking
	Measured	Modeled	% Error		
2007	125,796	71,056	(23)	14	VG
2008	72,462	99,182	96		
Average	99,129	85,119	14		

Table 5-5 Score Minimum and Corresponding Qualitative Grade for Nutrients

Ranking	VG	G	F	P
Absolute Percentage Error	30	70	120	180

Table 5-6 Water Quality Calibration and Validation stations in the Floyds Fork Watershed

USGS Station ID	Station name	Qualitative Score		Quantitative Score	
		TN	TP	TN	TP
Water Quality Station location: Main Stem- Floyds Fork					
03297830	Floyds Fork at Highway 53	G	G	38	32
03297845	Floyds Fork near Crestwood	G	F	51	78
03297900	Floyds Fork near Peewee Valley	G	F	45	72
03297930	Floyds Fork at Echo trail bridge	G	F	70	79
03298000	Floyds Fork at Fisherville	G	G	51	48
03298120	Floyds Fork at Seatonville Road	G	G	48	63
03298200	Floyds Fork near Mt. Washington	G	VG	57	14
03298470	Floyds Fork near Shepherdsville	G	G	58	44
EFFFF001	Floyds Fork at Ash Avenue	VG	G	18	45
EFFFF002	Floyds Fork at BardStown Road	G	VG	47	21
EFFFF003	Floyds Fork at Old Taylorsville Road	G	VG	44	21
Water Quality Station location: Tributaries					
03297850	South Fork Curry's Fork at Moody Lane	G	G	64	64
03297855	South Fork Curry's Fork at Highway 393	VG	G	2	33
03297860	North Fork Curry's Fork at Stone Ridge road	G	G	45	70
03297875	Ashers Run at Abbott lane near Crestwood	G	G	43	53
03297880	Currys Fork near Crestwood	VG	G	19	39
03297950	Long Run at Old stage coach road	VG	VG	3	20
03297975	South Long Run at Hobbs Lane	VG	G	6	61
03297980	Long Run near Fisherville	VG	G	20	55
03298005	Pope lick at South poope lick road near Fisherville	VG	VG	6	19
03298020	Cane Run at Thurman Road	VG	G	29	64
03298100	Pope lick at pope lick road near Middletown	G	G	55	64
03298110	Pope lick at Rehl road near Fisherville	VG	VG	19	13
03298135	Chenoweth Run at Ruckriegal Parkway	G	G	41	39
03298138	Chenoweth Run at Jeffersontown STP at Jeffersontown	G	G	67	53
03298150	Chenoweth Run at Gelhaus Lane near Fern creek	G	VG	65	27
03298160	Chenoweth Run at Seatonville road near Jeffersontown	G	G	44	44
03298250	Cedar Creek at Thixton Road	G	VG	55	6
03298300	Pennsylvania Run at Mt. Washington	VG	G	29	36
EFFCR001	Chenoweth Run # 1 at Gelhaus Lane	G	VG	50	23
EFFCR002	Chenoweth Run # 1 at Rickriegal Parkway	F	F	81	72

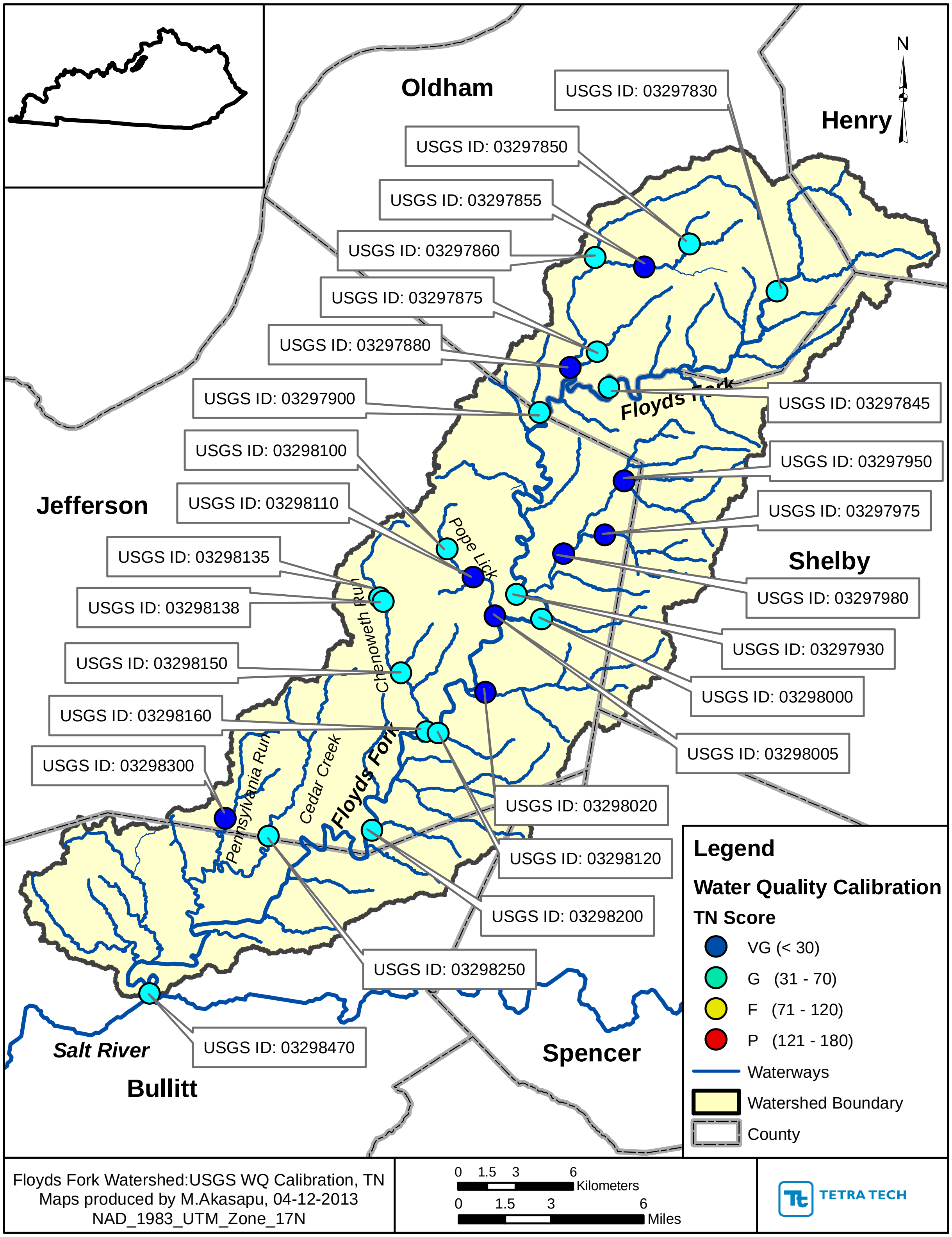


Figure 5-7 USGS WQ Calibration for TN in the Floyds Fork Watershed

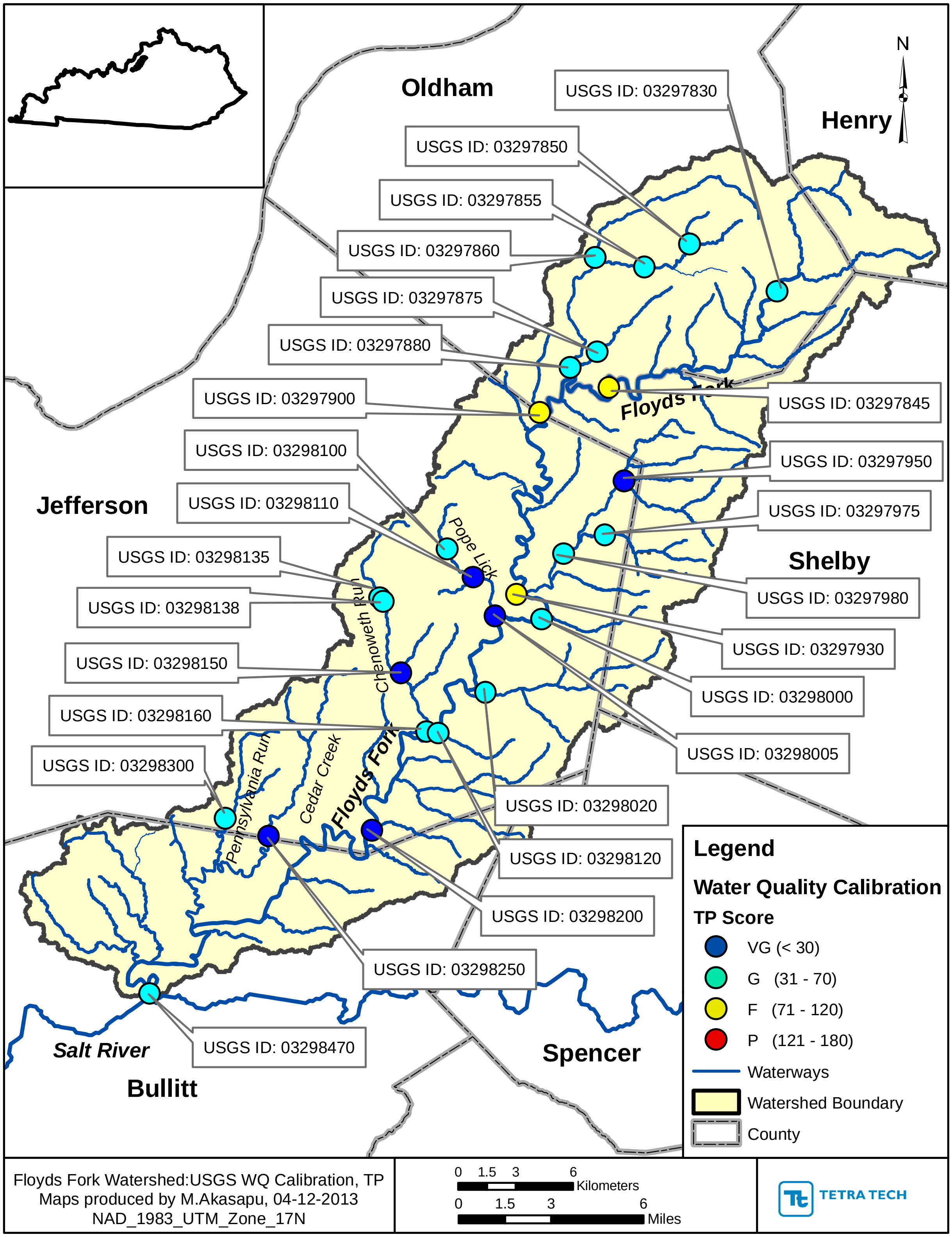


Figure 5-8 USGS WQ Calibration for TP in the Floyds Fork Watershed

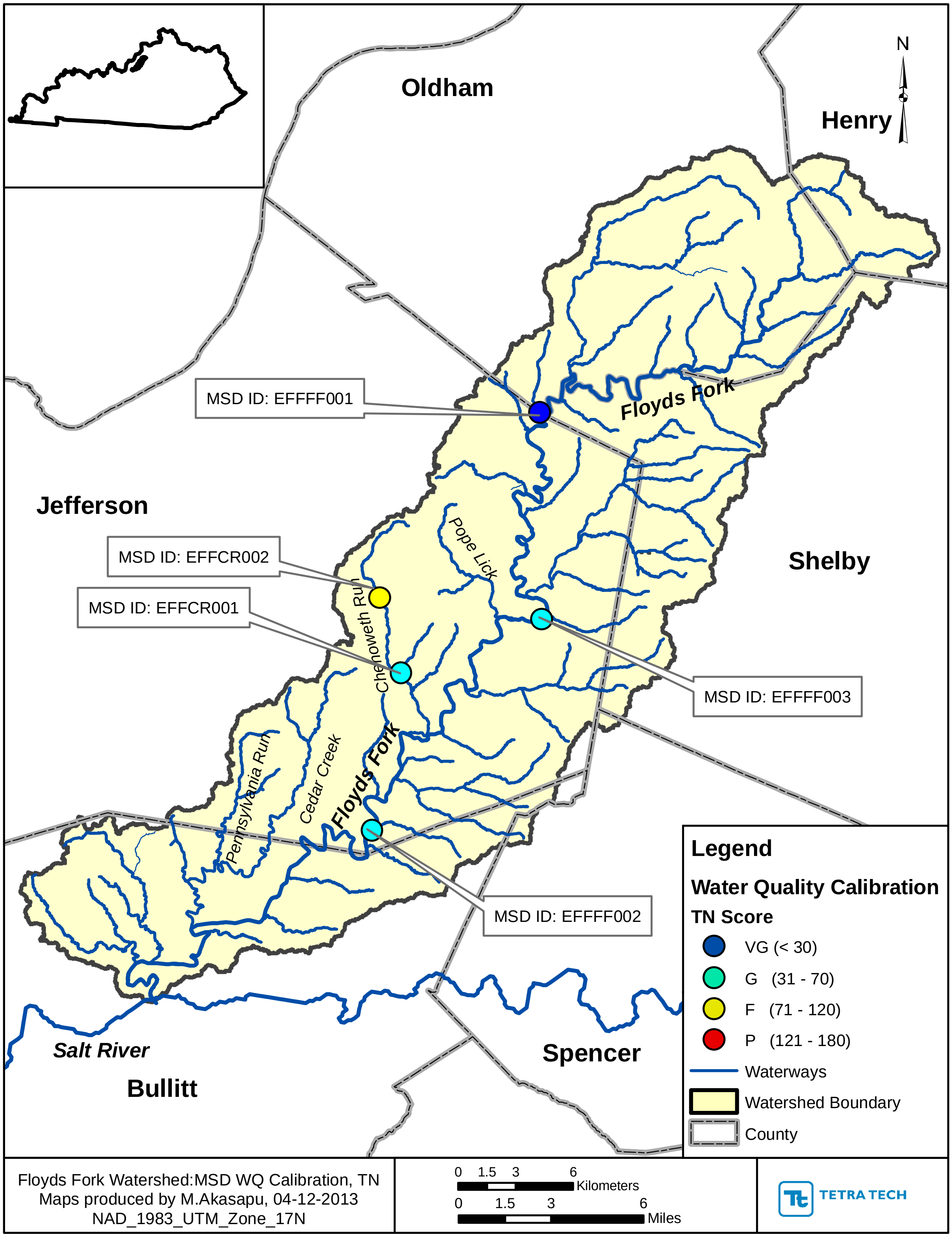


Figure 5-9 MSD WQ Validation for TN in the Floyds Fork Watershed

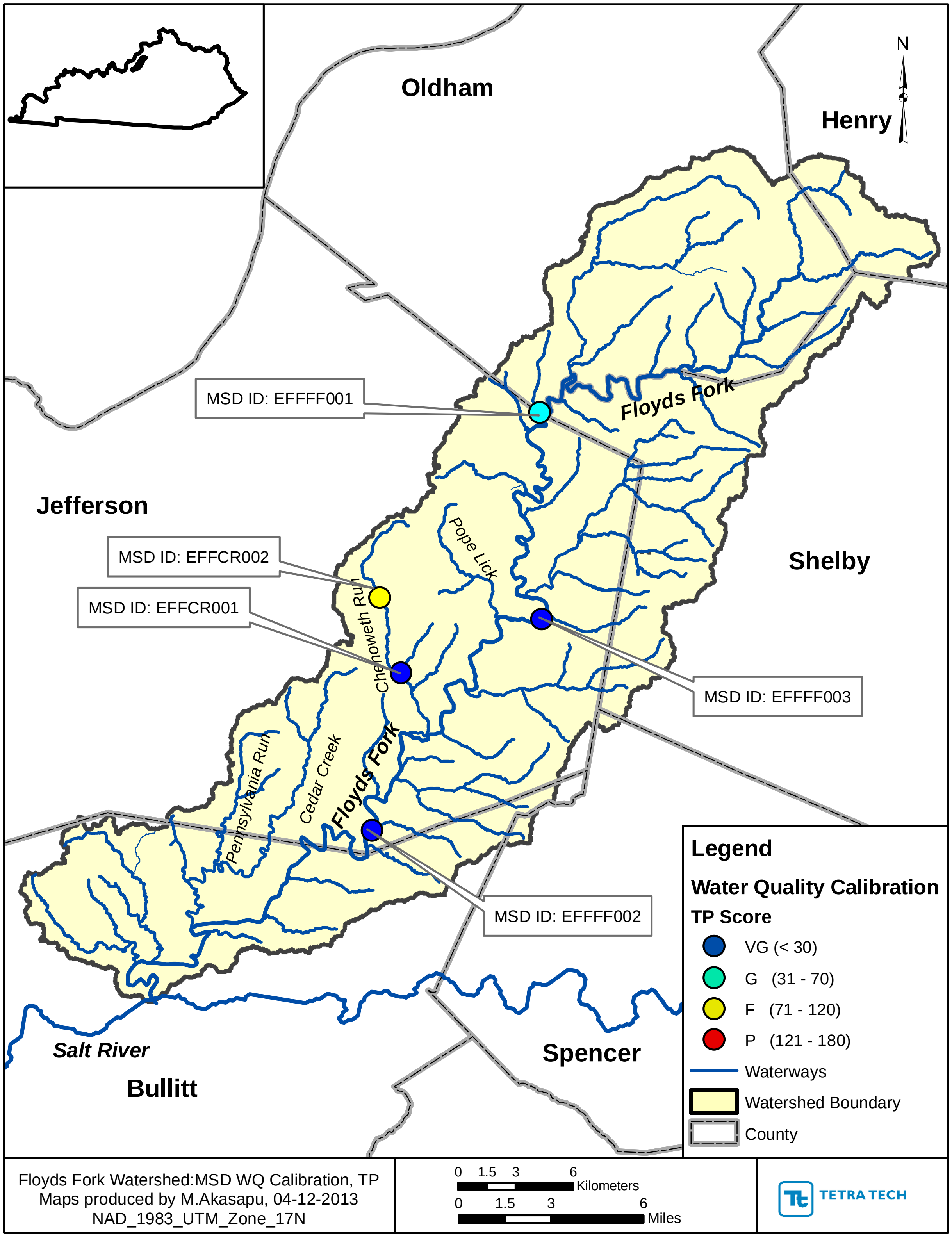


Figure 5-10 MSD WQ Validation for TP in the Floyds Fork Watershed

5.12 Loading Summary

Once the watershed model was calibrated, the percent of the total nutrient load being contributed by each pollutant source was calculated at each USGS flow gage. This information was particularly helpful in identifying the pollutant sources contributing the most nutrient loads at a particular USGS station. Table 5-7 summarizes the percent loading by source for TN and TP at the seven USGS flow gages. This information is presented graphically in Figures 5-11 and 5-12.

Table 5-8 presents the magnitude of loads as a percentage of the total load at the outlet of the Floyds Fork watershed for TN and TP at all 26 USGS water quality stations. Negative percentages indicate influence from water withdrawals and sinkholes.

Table 5-7 Summary of the percent loading for TN and TP at USGS Flow gages

Percent Loading Breakdown Summary for TN							
Location:	Main Stem: Floyds Fork			Chenoweth Run (Lower)		Cedar Creek	Pennsylvania Run
Station / Source	03297900	03298000	03298200	03298135	03298150	03298250	03298300
Point Source	22%	20%	24%	0%	67%	57%	10%
Sanitary Sewer Overflow	0%	0%	0%	0%	1%	0%	0%
Septics	0%	0%	0%	0%	0%	0%	0%
Water Withdrawal	0%	0%	0%	0%	0%	0%	-1%
Springs	1%	1%	1%	2%	0%	0%	5%
Non-Point Source	77%	79%	75%	98%	32%	43%	86%
Percent Loading Breakdown Summary for TP							
Station / Source	03297900	03298000	03298200	03298135	03298150	03298250	03298300
Point Source	23%	24%	22%	0%	70%	65%	31%
Sanitary Sewer Overflow	0%	0%	0%	0%	2%	0%	0%
Septics	0%	0%	1%	1%	0%	0%	1%
Water Withdrawal	0%	0%	0%	0%	0%	0%	-1%
Springs	2%	1%	1%	2%	0%	0%	2%
Non-Point Source	75%	75%	76%	97%	28%	35%	67%

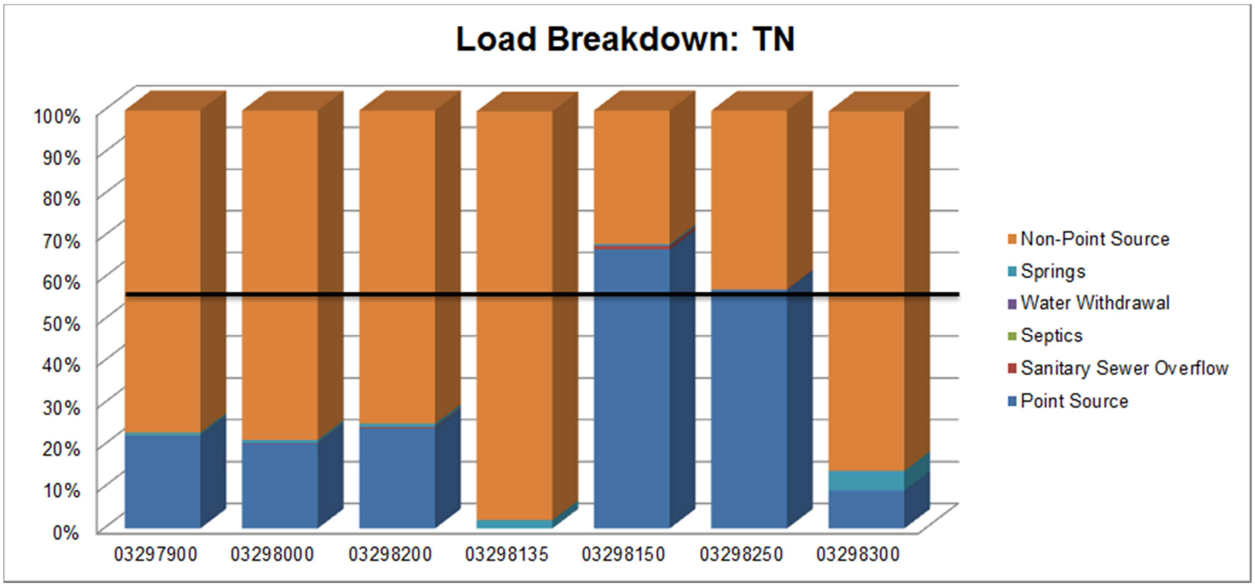


Figure 5-11 Percent Loading Breakdown for TN at USGS Flow gages

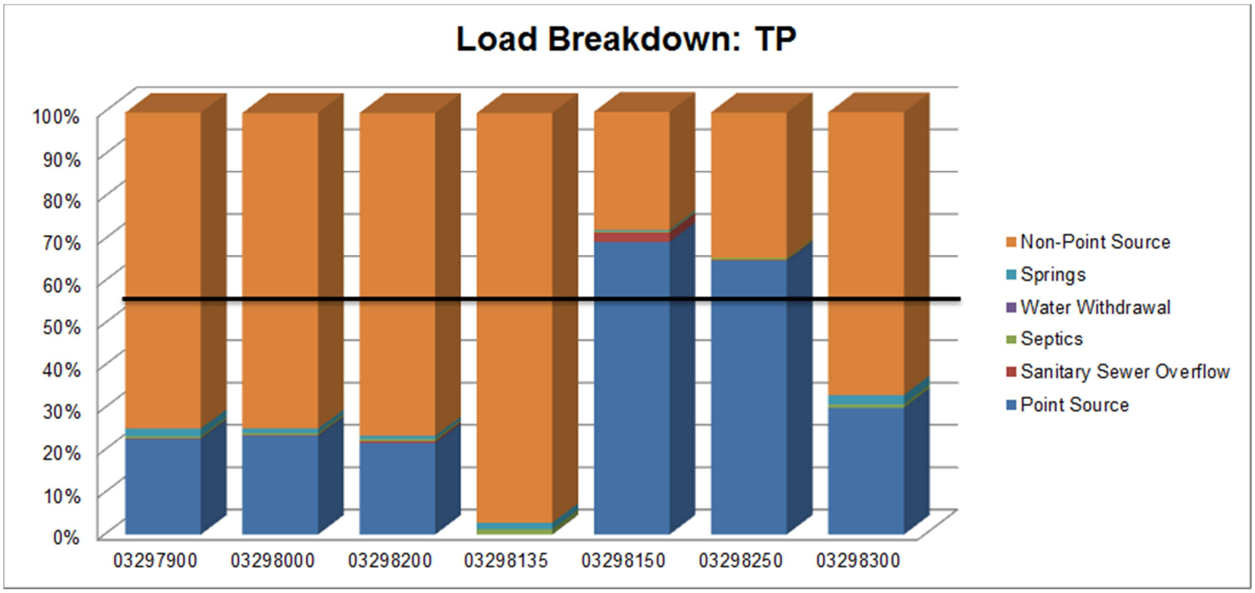


Figure 5-12 Percent Loading Breakdown for TP at USGS Flow gages

Table 5-8 Summary of the percent of magnitudes of loads for TN and TP at all USGS Water Quality Stations

USGS Station	SWS	TN			TP		
		Total (PS+NPS)	PS	NPS	Total (PS+NPS)	PS	NPS
03297830	244	7.8%	0.1%	7.7%	7.0%	0.2%	6.8%
03297845	229	9.0%	0.0%	9.0%	7.5%	0.0%	7.5%
03297850	220	0.6%	0.2%	0.4%	1.4%	0.7%	0.7%
03297855	215	2.7%	0.1%	2.6%	2.3%	0.1%	2.2%
03297860	210	12.6%	8.1%	4.5%	6.7%	3.1%	3.6%
03297875	225	1.2%	0.0%	1.2%	0.8%	0.0%	0.8%
03297880	617	2.1%	-0.5%	2.6%	2.9%	0.5%	2.4%
03297900	615	2.9%	0.9%	2.0%	4.7%	3.0%	1.7%
03297930	185	10.4%	4.4%	6.0%	10.7%	6.5%	4.2%
03297950	263	2.0%	0.0%	2.0%	2.5%	0.0%	2.5%
03297975	274	3.1%	0.0%	3.1%	3.0%	0.0%	3.0%
03297980	258	4.0%	0.0%	4.0%	5.8%	0.1%	5.7%
03298000	180	2.4%	-0.4%	2.8%	3.3%	-0.4%	3.7%
03298005	174	2.5%	0.0%	2.5%	2.3%	0.0%	2.3%
03298020	283	3.9%	0.0%	3.9%	5.0%	0.0%	5.0%
03298100	178	0.8%	0.0%	0.8%	0.3%	0.0%	0.3%
03298110	176	-0.3%	0.0%	-0.3%	0.0%	0.0%	0.0%
03298120	169	-1.6%	-1.3%	-0.3%	1.8%	-1.2%	3.0%
03298135	167	3.1%	0.0%	3.1%	1.4%	0.0%	1.4%
03298138	610	13.5%	13.0%	0.5%	8.0%	7.5%	0.5%
03298150	609	2.7%	0.0%	2.7%	3.1%	1.2%	1.9%
03298160	158	0.7%	-0.5%	1.2%	0.9%	-0.3%	1.2%
03298200	606	1.5%	-2.5%	4.0%	6.8%	-1.7%	8.5%
03298250	134	12.0%	6.8%	5.2%	8.3%	5.4%	2.9%
03298300	130	3.4%	0.4%	3.0%	2.6%	0.8%	1.8%
03298470	102	-2.8%	-4.8%	2.0%	1.1%	1.3%	-0.2%
Total		***100%***	***24%***	***76%***	***100%***	***27%***	***73%***

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